SLATT UNDERGRADUATE RESEARCH FELLOWSHIP
FINAL REPORT

SCHOLAR NAME:	Zachary W. Muetzel
FACULTY ADVISOR:	William Phillip
PROJECT PERIOD:	January – May 2023
PROJECT TITLE:	Development of 3D-printed modules to evaluate the performance of photoresponsive polymer membranes
CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):	**(X) Energy Conversion and Efficiency** **( ) Sustainable and Secure Nuclear** **( ) Smart Storage and Distribution** **( ) Transformation Solar** **( ) 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
Design modules with lights in various configurations and evaluate the intensity of light striking the membrane surface	Solidworks modeling software was used to design multiple module variations. The designs were chosen using geometric measurements and calculations to determine the refraction of light through water and air. The successful design was quantified by maximizing the intensity of light at the membrane surface.	100
Leverage Notre Dame resources to produce chosen designs	The module with the most promising result from the design stage was printed in collaboration with the Myung Lab at Notre Dame, using the appropriate additive manufacturing techniques.	100
Evaluate and incorporate the best design into existing testing infrastructure	The produced design is almost incorporated into the existing membrane testing infrastructure, although changes to experimental code and automation still need to be updated to account for the changes.	50

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	
EXTERNAL AWARDS RECEIVED	
JOURNAL ARTICLES IN PROCESS OR PUBLISHED	
BOOKS AND CHAPTERS RELATED TO YOUR RESEARCH	
PUBLIC PRESENTATIONS YOU MADE ABOUT YOUR RESEARCH	
AWARDS OR RECOGNITIONS YOU RECEIVED FOR YOUR RESEARCH PROJECT	
INTERNAL COLLABORATIONS FOSTERED	Nosang Myung, Notre Dame CBE Department, access to SLA 3D printers, 1 Interaction Faraj Al-badani, Notre Dame CBE Department, assistance with SLA printing capabilities, 3-5 Interactions
EXTERNAL COLLABORATIONS FOSTERED	
WEBSITE(S) FEATURING RESEARCH PROJECT	
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	

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 research experience allowed me to leverage my interest and experience in design, modeling, and 3D printing with Solidworks. By utilizing a variety of resources at Notre Dame, I was able to receive the help I needed to continue making progress toward my research goals. To complete the research objectives completely, more time would have been needed. Nevertheless, I am satisfied with the work completed and confident that future researchers can complete the last, unfinished objective.

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.)

"Smart" materials have gained traction in recent years due to their ability to respond selectively to stimuli in a variety of applications and industries. In separation processes, smart membranes are being examined for their ability to change pore size when stimulated. This increased control can be leveraged to modulate mass transfer across the membrane surface, thereby increasing the flexibility and versatility of the material. Photoresponsive membranes, those that undergo chemical changes when exposed to light of a specific wavelength and intensity, are of particular interest as light is a cheap, safe, and chemical-free stimulus that can alter membrane configuration.

Photoresponsive membranes have already been synthesized, such as those detailed in the paper entitled *Smart light responsive polypropylene membrane switching reversibly between hydrophobicity and hydrophilicity for oily water separation* (Jour. Membr. Sci. 2021, 638, 119704). However, no dead end stirred cell (the accepted membrane testing configuration) designs currently exist that incorporate light sources to evaluate their performance. Such performance metrics include mass transfer across the membrane as a function of light intensity or angle relative to the membrane and the minimum ratio of lit to dark time the membrane needs to achieve a desired level of separation.

The objective of the proposed research was to create a modified stirred cell that includes light sources positioned to provide consistent, direct light to the active surface of the smart membranes *in situ*. Multiple configurations were created to probe the effect of changing light position relative to the membrane surface. My previous work creating an automated membrane testing apparatus, detailed in the paper entitled *Device for the Acquisition of Dynamic Data Enables Rapid Characterization of Polymer Membranes* (ACS Appl. Polym. Mater. 2022, 4, 5, 3438–3447), provided opportunities to design custom 3D-printed parts, integrate those components with established membrane testing protocols, and automate the protocols to execute with minimal experimenter interaction. This prior experience prepared me for the proposed research objective. After the design is produced, the modified stirred cell can be incorporated into the ADD environment, allowing for automation of testing protocols unique to photoresponsive membranes, such as switching the light sources on and off automatically over the course of an experiment, and observing the corresponding changes in membrane throughput. This provides insight into the property change kinetics of photoresponsive membranes as a result of stimulus state changes.

To complete the above objectives, multiple modules were designed with lights in various configurations and the light intensity was measured to quantify the best design. After this design was chosen, Solidworks, a computer-aided design (CAD) software was used to create physical modules. The resources of in-lab PLA printers and the Myung Lab SLA printers were used to iterate and produce a physical copy of the best design. This allowed the new module to be integrated into the existing membrane testing infrastructure. Figure 1 below shows a model of the final design in Solidworks.

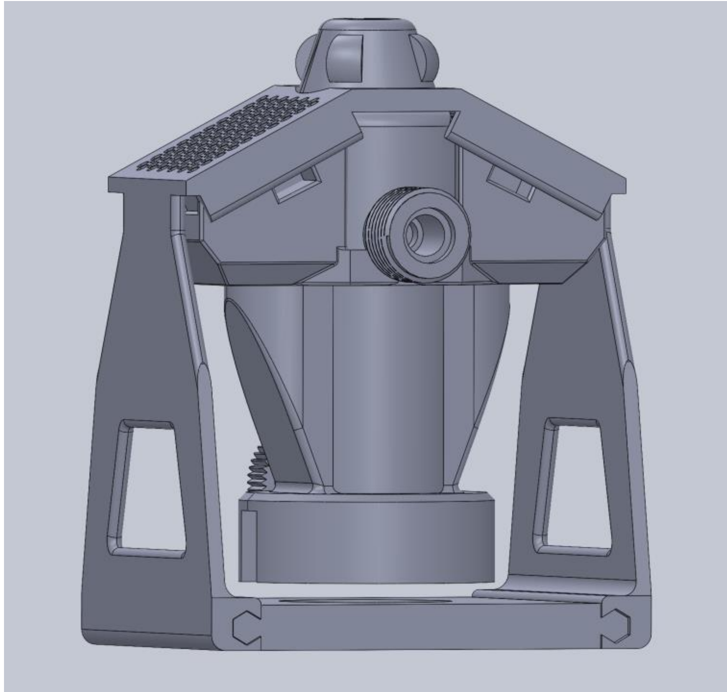

Figure 1. A physical rendition of the final module design, created in the computer aided-design software, Solidworks.

While the module design shown above in Figure 1 has been finalized and physically integrated into the existing testing infrastructure, there are changes that must be made to the testing code that automates the experimentation and data collection. By making the necessary changes, the existing infrastructure can be adapted to probe the different parameters (such as light exposure) automatically, allowing the new module design to be leveraged completely. This final research objective is being passed on to future Notre Dame researchers.