

NDnano Undergraduate Research 2020-21 Winter Session Project Summary

1. Student name: Grace Gasper

2. ND faculty name & department: Dr. Hsueh-Chia Chang – Department of Chemical & Biomolecular Engineering

3. Winter Session project title: Superparamagnetic Nanobeads and Nanomembrane for Virus Isolation and Detection

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

- Iterative design
- SLA 3D printing
- Membrane synthesis
- RT-PCR

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

Over one million screening tests for the COVID-19 virus are conducted every day in the United States. The nanomembrane would selectively filter viruses (including COVID-19) in order to provide rapid, high-yield and high-sensitivity isolation and identification from saliva or swab samples.

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

In the midst of an unprecedented global pandemic, there have been numerous issues with improving the accessibility, scalability, and accuracy of COVID-19 screening tests. One large issue is the high percentage of false negatives due to a low abundance of virus particles, analyte lost during dilution/extraction, or noise. The purpose of the project is to use the high-throughput and high-yield Asymmetric Nanopore Membrane (ANM) filtration technology for isolation and enrichment of virus particles in order to provide a rapid, cheap, and accurate POC test.

One-page project summary that describes problem, project goal and your activities / results:

The goal of this project is to develop a microfluidic device to selectively isolate virus molecules in order to reduce sample dilution and sensor signal noise for COVID-19 testing samples. The current PCR test used for sample testing is slow and results in false negatives too frequently, which can lead to an exponential growth of new infections. These issues are addressed through the integration of Dr. Chang's Asymmetric Nanopore Membrane (ANM) technology with the goal of improving sensitivity and selectivity of the virus tests.

Application of the ANM filtration technology requires a membrane holder in order for the microfluidic device to function. This holder is developed through SLA 3D-printing technology. SLA is form of 3D printing in which monomers and oligomers are cross-linked together by the presence of UV light to produce polymers in a layer by layer fashion. Multiple issues arose with the design and implementation of this membrane holder, and new design decisions were made in an attempt to circumvent these problems.

One issue that occurred was that the tension created when sealing the membrane holder during the experiment created fractures within the holder. The nanomembrane is sealed within the polymer holder using miniature screw. In order to prevent leakage during the virus isolation step, the screws are tightened as much as possible. It became apparent that such tension on the polymer material created fractures near the screw site, effectively ruining the seal of the membrane holder. In order to overcome this issue, the dimensions of the holder were changed. Iterative design was used to determine the best height dimensions for both the top and bottom pieces of the holder. It was also necessary to determine the systematic error of the SLA printer.

During the winter I also worked on a project focused on anion exchange membrane synthesis for detection of nucleic acid. When negatively charged particles pass through an anion exchange membrane, distinct current-voltage characteristic (CVC) curves are produced. These curves have three distinct phases. Initially, there is an increase in both current and voltage, which is a result of the abundant concentration of anions moving through the membrane. Eventually the anion concentration on one side of the membrane depletes, and this is displayed on the CVC curve through an increase in voltage with little to no increase in current. Finally, microvortices are developed on the surface of the membrane to bring forth new anions and an equal increase in current and voltage is seen once again. When nucleic acids are functionalized on the surface of this anion exchange membrane, they increase the lag time before the microvortices form. This results in a noticeable shift in the CVC curve. Existing membrane models lack sensitivity and produce only a minor shift. The goal of this project is to develop a membrane which yielded a large enough shift to definitively signal the presence and concentration of nucleic acid.

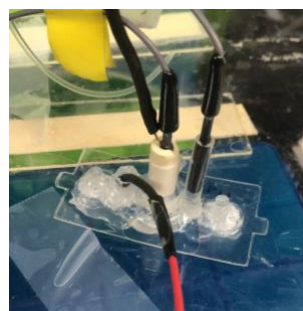


Figure 1. Sensor-chip device with Gamtry probes

My role in this project first involved synthesizing this new membrane based on chemical ratios given in a previous research paper. The difference between our membrane and past ones would be a textured surface to increase the delay in microvortices' development. I was responsible for not only synthesizing the membrane but also designing the proper mold to create this textured surface. After each membrane prototype was completed, a miniscule piece of it was used to create a sensor. The sensor was inserted into a microfluidic chip and the CVC measurements were made using Gamtry Instruments Software. Iterative design was enacted after every CVC curve was analyzed, and the final membrane had a width of 0.6 mm and its surface was molded from micro grit sandpaper. During the spring semester, I will continue to work on this project and make improvements for an even larger CVC shift.