Access to Clean Water through Polyelectrolyte Based Membranes

Aggie-Challenge

Abstract

Water scarcity is one of the most serious global challenges, currently one-third of the world lives in water-stressed countries and that number is only projected to grow. The most bountiful supply of water on the planet is salt water; the process of desalinations can produce fresh water from salt water. Our project focuses on reverse osmosis membrane technology to ultimately reduce energy costs. Working in the Adaptive Soft Material Lab we are testing salt rejection rates of thin film polyelectrolyte membranes. The coating process for the membrane has four stages; these stages create layers of different charge. These differing charged layers prevent the Na\(^+\) and Cl\(^-\) ions from passing through the membrane and leave the water molecules to separate and pass through the film. Difficulties arose during the production of membranes thus our future work centers around the optimal design and fabrication of the membranes to reach prime salt rejection.

Membrane development

Our group of nine students was split up into two smaller groups. One group worked on devising a way to obtain reliable membranes while the other group planned out a larger, high-pressure apparatus. This apparatus would utilize the thin films developed by the first group for optimizing salt-rejection rates.

The membranes consisted of several components. The porous support used was a cellulose nitrate wafer. This hydrophilic base would allow water to pass through while supporting charged polyelectrolyte layers. Several methods were used to apply the layers onto the wafer including dip-coating, spin-coating, and spray-coating. In every case, the polyelectrolytes were prepared in a solution. The two polyelectrolytes were Poly(allyamine) hydrochloride (PAH) and Poly(acrylic acid) (PAA). Two beakers contained the respective solutions, each with 10 milliMolar concentration. In dip-coating, the wafers were simply dipped in the beakers and rinsed in water. In spray coating, the solutions were applied using a spray bottle. Finally, in spin-coating, a small syringe was used to apply the solution onto the spinning wafer.

All beakers, including the ones containing rinse water, PAA, and PAH were adjusted to a pH of 3.5, which is the optimum level for thin-film forming process. With these conditions, each new layer would intertwine with the previous layer upon application. Essentially, the complete membrane would desalinate incoming water by trapping the unwanted ions (e.g., Na\(^+\) and Cl\(^-\)) in the intricate network of oppositely charged PAH and PAA layers.

To test the selectivity rates of our membranes, we used a Buchner funnel with a vacuum attachment to create pressure and help force water through. The membranes were clamped between the lower reservoir and top funnel. Unfortunately, the fabrication methods tested so far have resulted in negligible selectivity. We have tried doubling the amount of bi-layers from 35 to 70 and did not see significant improvement. To try and diagnose the problem, we used Rhodamine-dyed PAH while spin-coating. After applying a couple of layers, we observed several uncoated gaps, suggesting that the membrane was coated unevenly.
Although we had obtained a working mechanism to test our selectivity rates (using the Buchner Funnel set up and a conductivity meter to quantify the amount of salt rejection), we have not yet been able to obtain notable salt rejection. The problem lies in the membrane fabrication itself. Once we can devise an effective way to coat our membranes, we can move onto the large apparatus testing.

**High Pressure Testing Apparatus**

While this first half of our research team focused on fabricating the membranes and testing under low pressures, the second half of the team concentrated on the design of a high pressure system that will be utilized upon successful fabrication of membranes that display more salt rejection.

The high-pressure system has not yet been testing, however the setup can still be described and appropriate expectations set. The polymer membranes are to be created using dip, spin or spray coating, and contained in the Sterlitech® CF042 Crossflow cell (see Figure 1.1). A high pressure electrostatic pump (Figure 1.2) will drive 700-800 psi to force the concentrate water through the membrane and into the substrate collection tank (Figure 1.6).

In order to control and maintain pressure, two Sterlitech® control valves (Figure 1.4) and a Mid-Hardware Gauge with “T” are to be used as shown.

Because the complete apparatus has yet to be tested, it is difficult to assign exact expectations of filtration abilities of the high-pressure system. At minimum, results similar to that of the low pressure Buchner Funnel with some increase in filtration are expected.

**Conclusions**

Access to clean water is an extremely important issue that our society faces today. Desalination via reverse osmosis using layer-by-layer membranes offers a solution. While the process of reverse osmosis is nearing its max efficiency, one major area for improvement that still exists is the membranes themselves. This semester, our group has focused on different coating processes to fabricate these membranes, utilizing dip, spin and spray coating techniques. While we have not found an optimal method yet, our future work will focus on finding an appropriate coating method and then determining the effects of using different polyelectrolytes on the performance of the membranes. We are also in the process of developing a high pressure testing device.

In future semesters, this device will be utilized to test the membranes we fabricate with the hope of increased salt rejection.