The Effect of Polymer Properties on Carbon Dioxide Absorbance Capacity of Supported Ionic Liquid Membranes

*Jarod Harris, Taylor Adams, Sarang Ismail, Mona Bavarian**
University of Nebraska-Lincoln, Department of Chemical and Biomolecular Engineering

NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH

Introduction

Supported Ionic Liquid Membranes (SILMs) are a recent technological advancement in the field of carbon capture. SILMs are comprised of a polymer and an ionic liquid mixed in a solvent, and the options for each are numerous. Countless ionic liquids exist, but focus has been given to imidazolium-based ionic liquids, as they tend to be liquid at room temperature and have many properties ideal for carbon capture. Namely, the ionic liquids have a high CO_2 selectivity and tunability while also featuring a low viscosity and volatility. When compared to industrially available alternatives like MEA which are known for releasing harmful and carcinogenic amines, SILMs do not release such hazardous chemicals into the air during the process. Much work has been done on the optimization of SILMs to ensure their efficacy. A comprehensive analysis of the SILM technology is required to allow for effective implementation. The use of SILMs has also been investigation in combination with other compounds, including MXenes and GNP, and future work will investigate the addition of block copolymers and (poly)ionic liquids, as both advances provide promising results for their joint implementation for carbon capture.

Experimental Methods

- Solvent:PVDF solution is made at 5 weight% PVDF for both image analysis and absorbance testing
- The solution is heated and Emim-Tf_2N is added in a 1:1 ratio and heated again under milder conditions.
- Finally, the solution is spin coated onto the desired substrate and dried in a vacuum oven for 3 days.

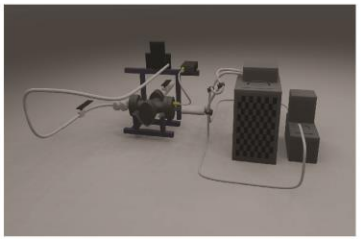


Figure 1: Rendering of the Experimental Apparatus

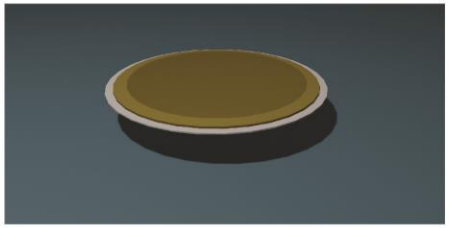


Figure 2: Rendering of a coated Quartz Crystal substrate

Heat of Sorption

The heat of sorption refers to the energy released or absorbed during the process of capturing and storing CO_2. This energy exchange directly influences the efficiency and cost-effectiveness of the carbon capture process. Understanding and optimizing the heat of sorption is crucial for designing highly efficient capture systems. Using Clausius-Clapeyron equation, the recorded temperature and the calculated mass absorbed, the heat of sorption may be interpolated from the slope of the isobaric sorption plot, like the one shown in Figure 3.

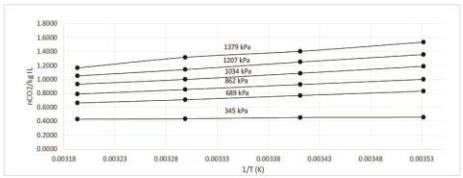
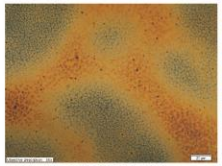


Figure 3: Isobaric Heat of Sorption Plot

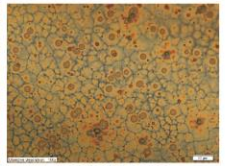
$$\frac{d\left(\ln\left(\frac{P}{P^o}\right)\right)}{d\left(\frac{1}{T}\right)} = \frac{-\Delta H_{ads}}{R}$$

Clausius-Clapeyron Equation was used to determine the heat of sorption. Heat of sorption analysis is used for large scale energy analysis.

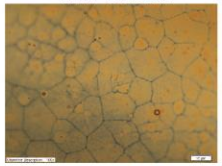
Surface Analysis



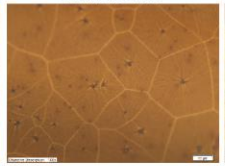
534k PVDF:DMAc



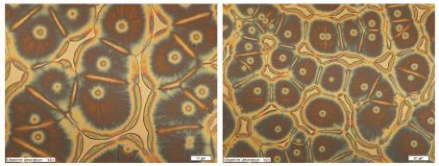
534k PVDF:DMF



534k PVDF:DMAc:Acetone



534k PVDF:TEP



534k PVDF:TEP:EmimTF2N

Polarized Light Microscopy was used to characterize films, using silicon wafer as the substrate for high-quality imaging. The formation of spherulites differs based on the solvent used, with TEP showing the most uniform formation. Uniform films are incredibly important for their ease of repeatability. However, other considerations must be made, including the toxicity of the solvent and the solubility of the polymer in solution. TEP notably displays lower solubility parameters compared to DMF and DMAc. In an attempt to improve the uniformity in the film, acetone was introduced in the DMAc solution, which did improve the formation of spherulites on the surface.

CO_2 Absorbance VS. MW

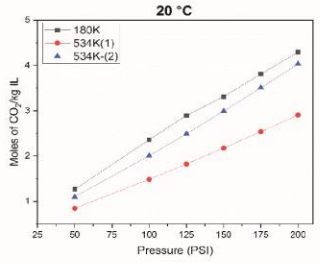


Figure 4: Comparison of CO_2 sorption and pressure at 20C

Each sample was tested at 10°C, 20°C, 30°C, and 40°C, and at pressures ranging from 50 to 300 PSI. Due to differences in the films and QCRs, each film was tested to unique specifications. Figure 4 shows the trend of the pressure applied and the CO_2 absorbency of each of the samples. The trends displayed in Figure 4 follow Henry's Law. As a general rule the adsorbtion values are highest at the lowest temperatures and highest pressures.

Conclusion

- Solvent-polymer interactions play a very important role in spherulite formation, with TEP providing the most uniform films. The addition of acetone to DMAc samples also proved effective.
- Further heat of sorption calculations must be done to ensure accuracy amongst the results.
- The heat of sorption was found to be 7.75-16.26 kJ/mole CO_2 adsorbed, which is significantly lower than industrially available technologies such as MEA, with reported values between 20 and 65 kJ/mol.

Acknowledgments

This work was supported by the Nebraska Public Power District through the Nebraska Center for Energy Sciences Research at the University of Nebraska-Lincoln.