NDnano
Center for Nano Science and Technology

ND*nano* Summer Undergraduate Research 2017 Project Summary

1. **Student name & university**: Sushree Jagriti Sahoo (IIT Delhi)

2. **ND faculty name & department**: Prof. William Phillip (Department of Chemical and Bio-molecular Engineering)

3**. Project title**: Elucidating fundamental transport properties of copolymer-derived charge mosaic membranes

4. **New skills acquired during my summer research:**
I believe that during my summer research, I got a lot of exposure to laboratory based experiments. I learnt how to perform experiments with precision. I learnt how to run the diffusion cells and make calibration curves for different salt solutions. I explored a lot of features of Microsoft Excel and Microsoft Powerpoint. I understood how to analyze a large set of data and what things should be included while making a presentation. I learnt how to give a presentation in lab group meetings.

5**. Practical application/end use of my research:**

The idea of nano porous membranes based on self-assembled copolymer precursors is emerging as a promising tool of separation and purification. These can find applications in water purification, pharmaceutical and biofuel processing applications. The reverse osmosis technique which is being used these days is very energy intensive method so the charged mosaic membranes provide a more efficient way of purifying the wasterwater.

6. **Abstract**

W.A.T.E.R lab has developed charge mosaic membranes that facilitate diffusion of charged solutes over water through oppositely charged regions. These are being fabricated by ink-jet printing polymeric materials onto a structural template. The CMMs are being printed by using the striped pattern which is alternatively printing positively charged and negatively charged polyelectrolytes.
To develop an understanding of how these membranes function, we conducted diffusion cell experiments for salts of varying valency, having different concentrations and ionic mobility. Through the experimental water flow and solute throughput tests, we were able to elucidate how the nanoscale structure and chemical functionalities of the membranes impact the observed transport properties.

7. **References**

1. Gao, Peng, Aaron Hunter, Mark J. Summe, and William A. Phillip. "A Method for the Efficient Fabrication of Multifunctional Mosaic Membranes by Inkjet Printing." *ACS applied materials & interfaces* 8, no. 30 (2016): 19772-19779.
2. Cussler, Edward Lansing. *Diffusion: mass transfer in fluid systems*. Cambridge university press, 2009.
3. Kamcev, Jovan, Michele Galizia, Francesco M. Benedetti, Eui-Soung Jang, Donald R. Paul, Benny D. Freeman, and Gerald S. Manning. "Partitioning of mobile ions between ion exchange polymers and aqueous salt solutions: importance of counter-ion condensation." *Physical Chemistry Chemical Physics* 18, no. 8 (2016): 6021-6031.

Project summary

MOTIVATION:

Desalination of water by reverse osmosis is the most common method of producing potable water but it is energy intensive due to fundamental thermodynamic restrictions. Therefore, water reuse an also be an important component of the water supply portfolio. Water reuse attempts to use non-traditional sources for a beneficial purpose, e.g., reclaimed wastewater for irrigation where trace amounts of contaminants, such as nitrates, perchlorates, and heavy metals are hazardous to human health. We designed, charge mosaic membranes (CMMs) that facilitate diffusion of charged solutes over water through oppositely charged regions. Rather than forcing 99.9% of solution through a size-selective membrane, it will be possible to remove only the small percent of contaminant.

OBJECTIVE:

To conduct diffusion cell experiments for different salts and study the fundamentals of ion transport and interaction of salt particles with monofunctionalized and charged mosaic membranes

PROCEDURE:

1. I made the calibration curves for all the salts by measuring conductivities for different concentrations
2. I performed diffusion cell experiments using salt solutions of 10mM and 100mM (KCl, $MgCl_2$, K_2SO_4, $MgSO_4$)
3. I also tried performing this test with some other monovalent salts(LiCl , NaCl, NH_4Cl, KNO_3) and uncharged membranes to study pure diffusion through these membranes

Fig: Diffusion cells

RESULTS:

- Role of valency (Mono-functionalised membranes)
    - Larger counterions (*e.g.* SO_4^{2-} in PDADMAC) diffuse faster than smaller counterions (*e.g.* Cl^{-})
    - Divalent coions show almost no diffusion (*e.g.* Mg^{2+} in PDADMAC)
    - Divalent coions have similar diffusion rates compared between positively- and negatively-charged membranes (*i.e.* Mg^{2+} in PDADMAC vs. SO_4^{2-} in PSS)
- Concentration
    - Higher concentration results in higher diffusion rates for all salts
    - KCl has the highest permeability through the mosaic membranes due to high diffusion coefficients, higher interactions with the charges on the membrane and small size

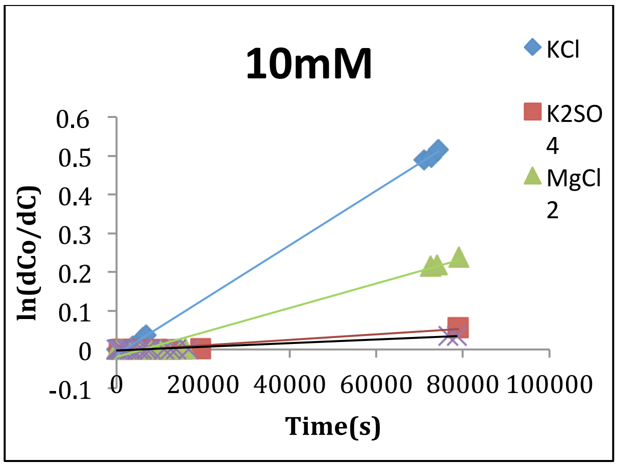
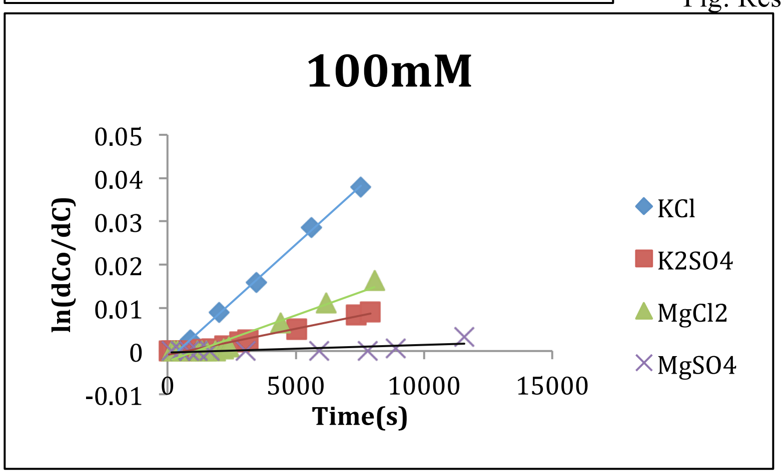


Fig: Results of permeation through mosaics



FUTURE WORK:

- Corroborate the results with new membranes
- Perform absorption experiments to study the interaction between ions in the salt solution and the surface charges on the membrane (PARTITION COEFFICIENT STUDY)