

# Space Grant FUNding: NASA Internships and Better Ways to Purify Water

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Chris Buelke

# Space Grants Received

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## NASA Internship Stipend

- Water purification research
- Summer 2015

## GRA Funding

- Lunar liquid-oxygen production facility feasibility study
- January 2015

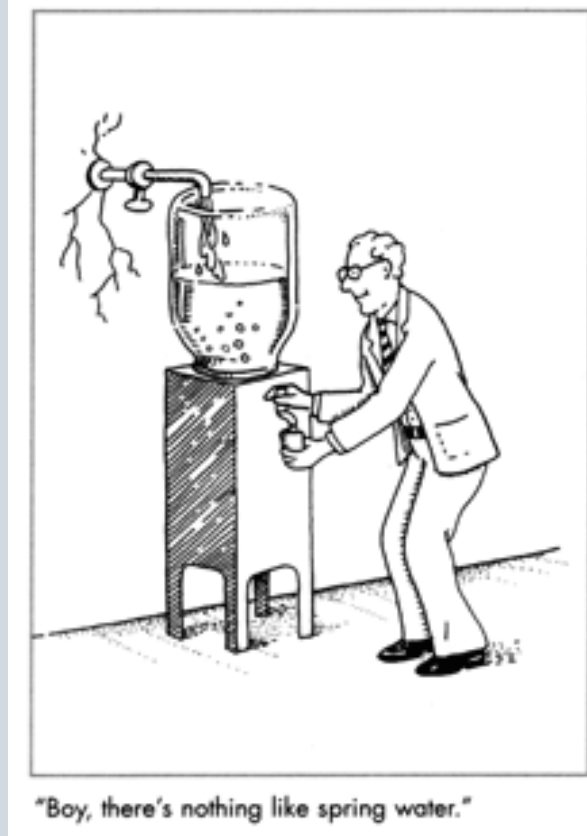
# The Water Purification Project

*Holey Graphene Membranes for Water Purification*

Advanced Materials and Processing Branch (AMPB)

Dr. John Connell and Dr. Yi Lin

“Step 1: Get a Drawing Board”



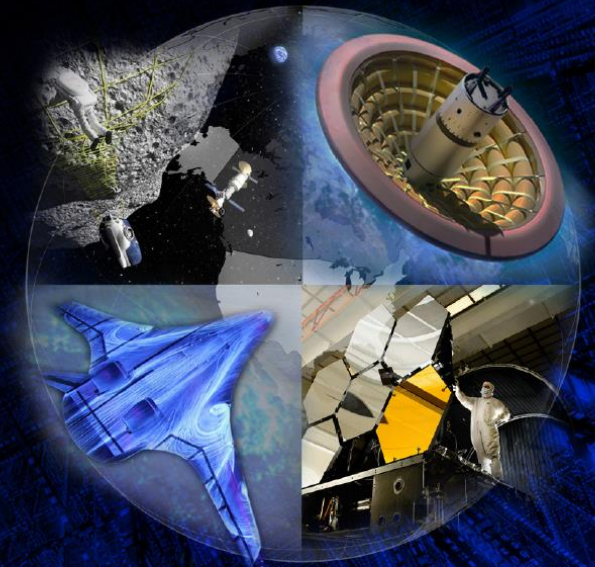
# Real Applications

## Life Support Systems

- NASA Technology Roadmap
- Closed-loop Water Recovery
  - Urine Purification
- Ion Exchange
  - NaCl, K<sup>+</sup>, Mg<sup>2+</sup>



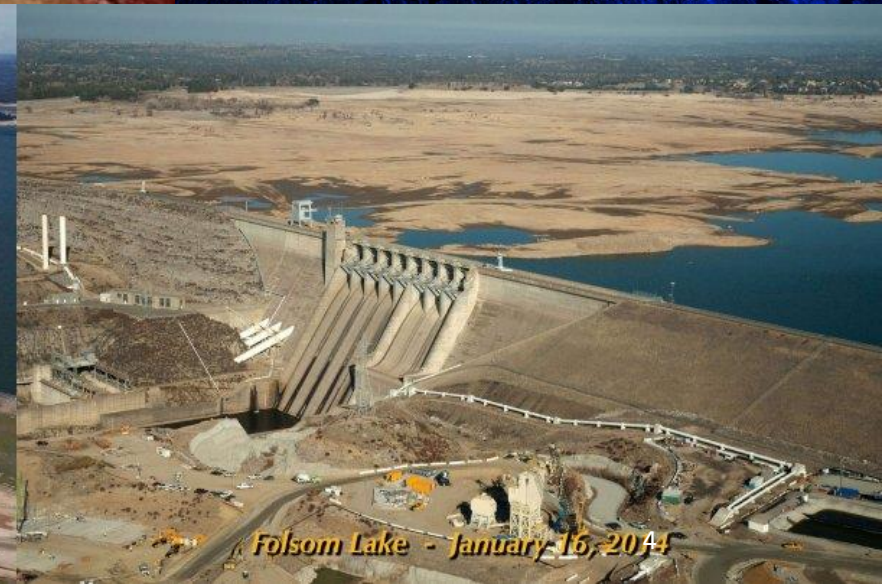
## NASA Technology Roadmaps TA 6: Human Health, Life Support, and Habitation Systems



May 2015 Draft

## Water Desalination

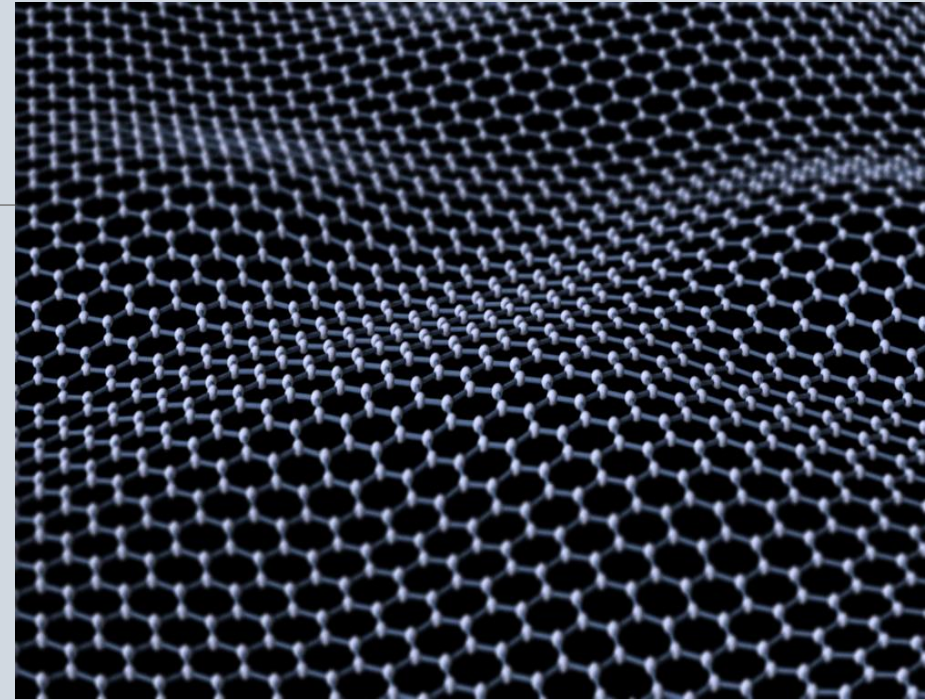
- More efficient
- Less cost
- “Blue Revolution”



# Background - Graphene

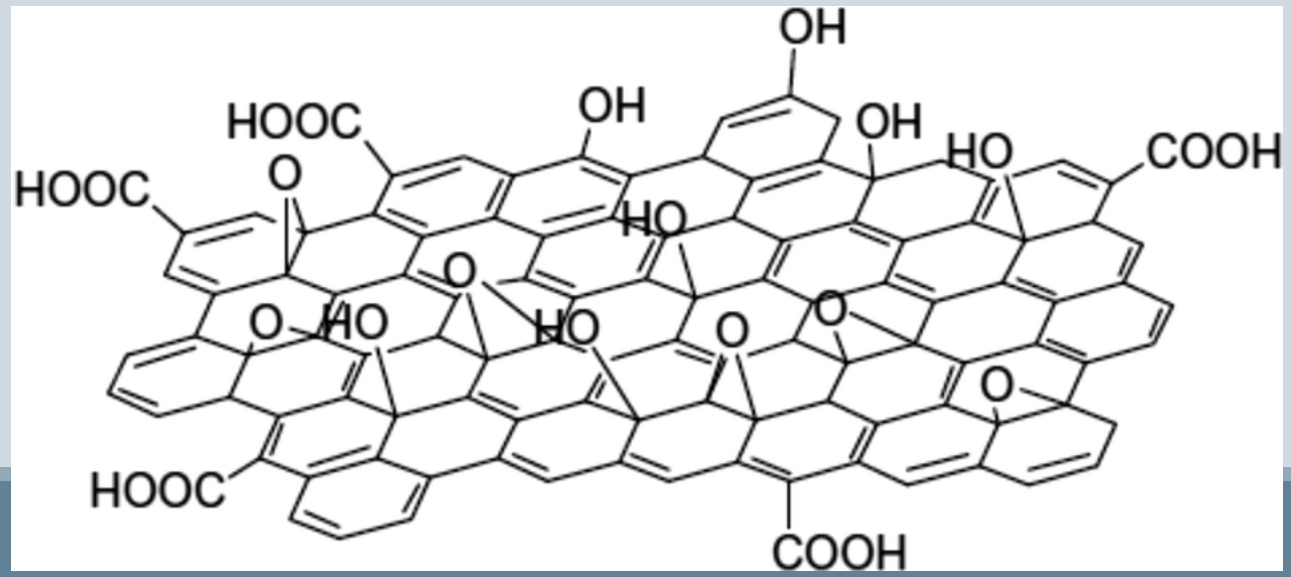
## Graphene

- C-C sheets
- Outstanding properties
  - Thermal/electric conductor
  - High tensile strength (> structural steel)
  - Lightweight



## Graphene Oxide (GO)

- COOH, OH and O functionalized



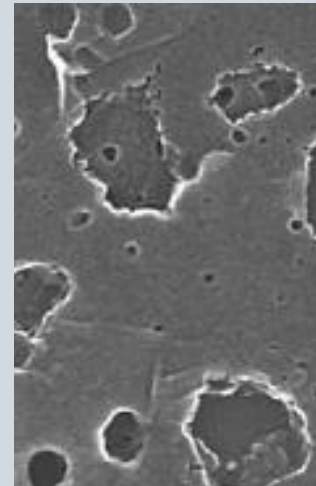
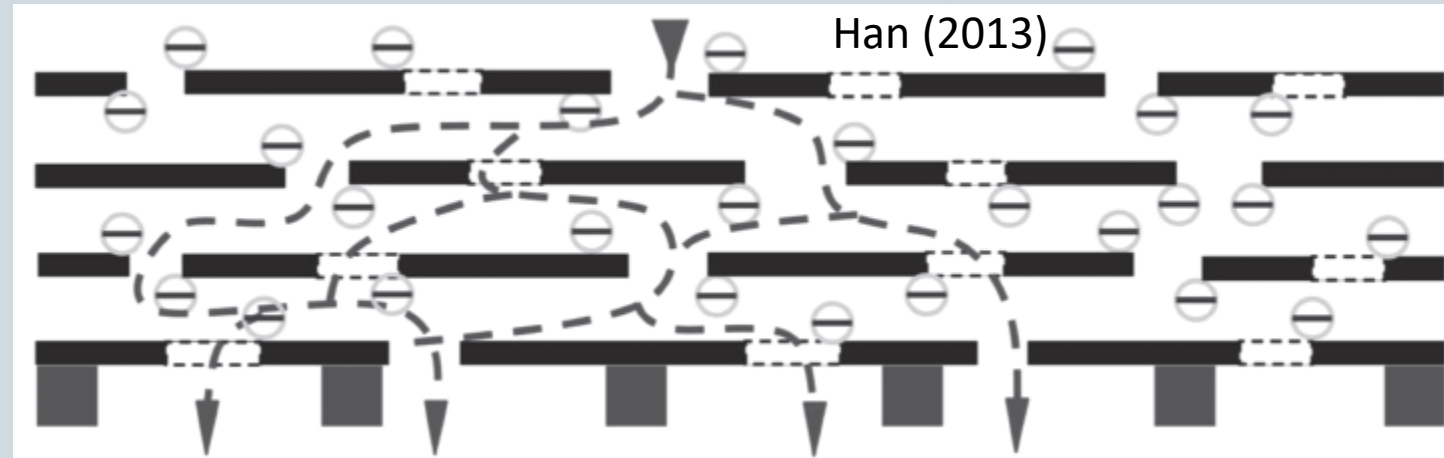
# Background - GO for Molecular Transport

## Forms of Graphene

- Graphene
- Graphene Oxide
- Holey Graphene (Oxide)

## Great Properties

- Selective Seal
  - Helium is halted (Nair 2013)
  - Water unimpeded (Grossman 2012, Han 2013, Hu 2013)
- Ion Rejection
  - Monovalent/divalent ions (Grossman 2012, Han 2013, Hu 2013, Joshi 2014, Sun 2015)



# Project Objectives

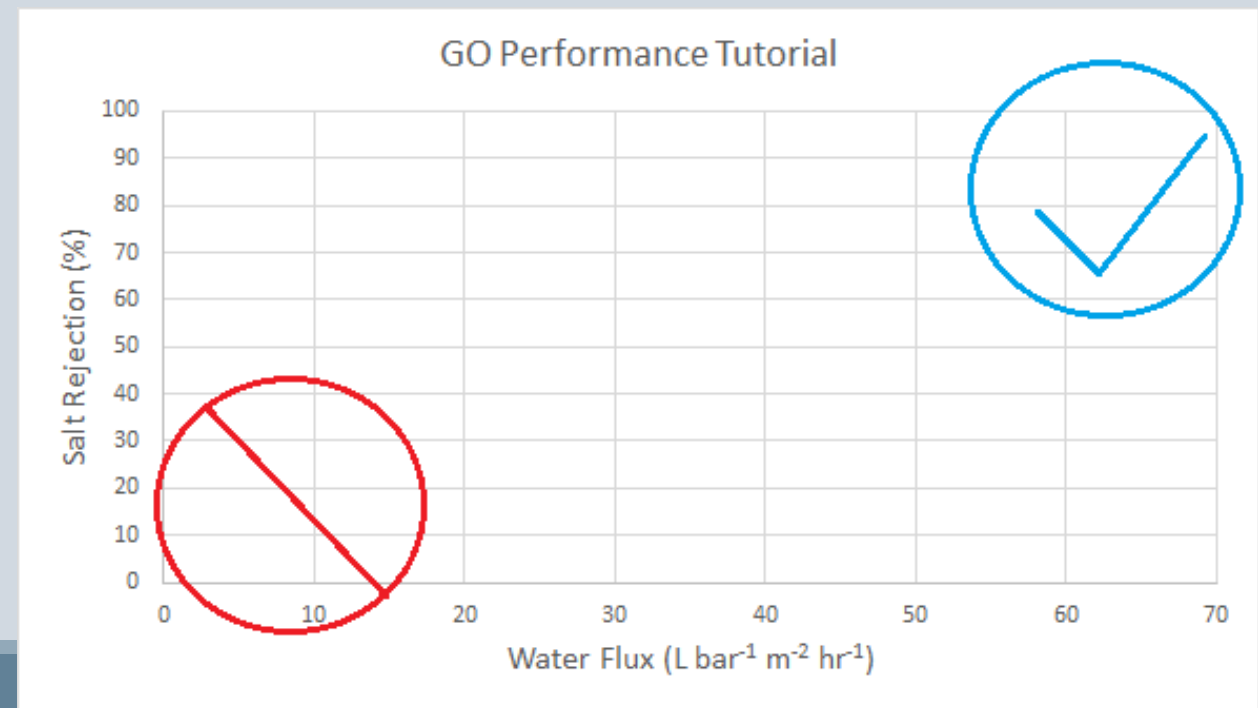
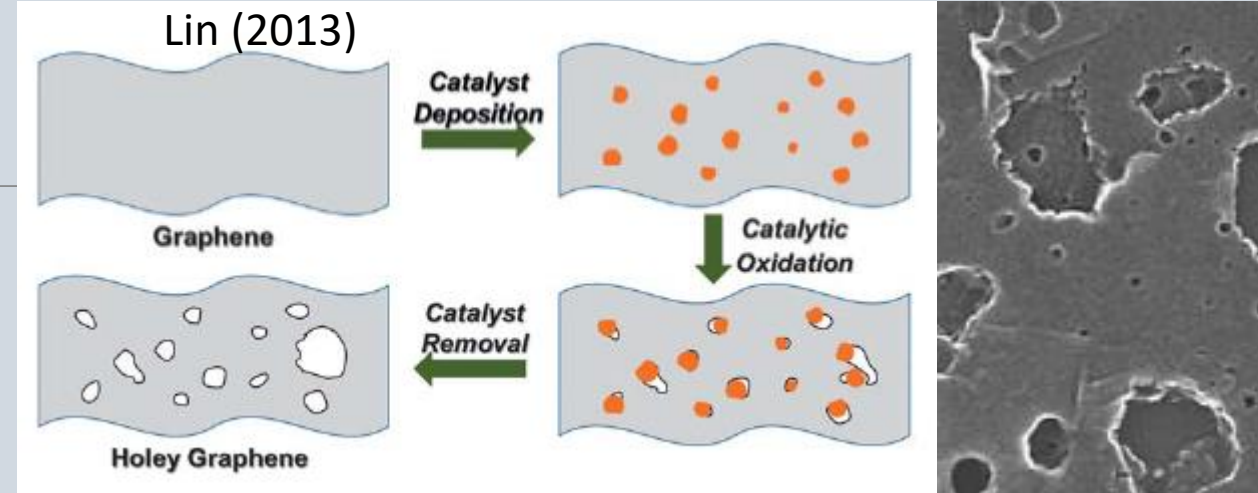
## Initiate Project

### Investigate Multiple Types GO

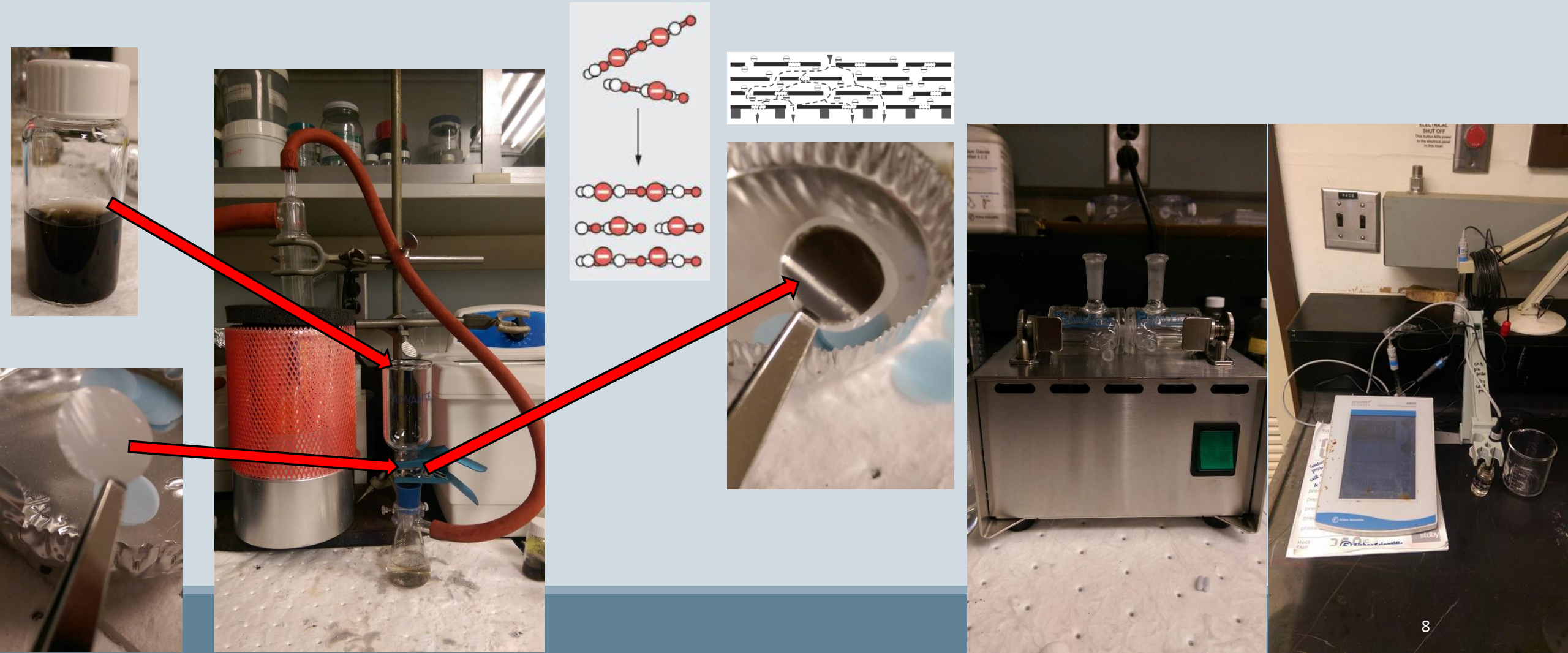
- “hGO v1” (in-house, small holes)
- “hGO v2” (in-house, large holes)
- GO (commercial)

### Investigate

- Ion Rejection
  - NaCl, KCl, MgCl<sub>2</sub>
- Water Flux
- Varying Membrane Thickness

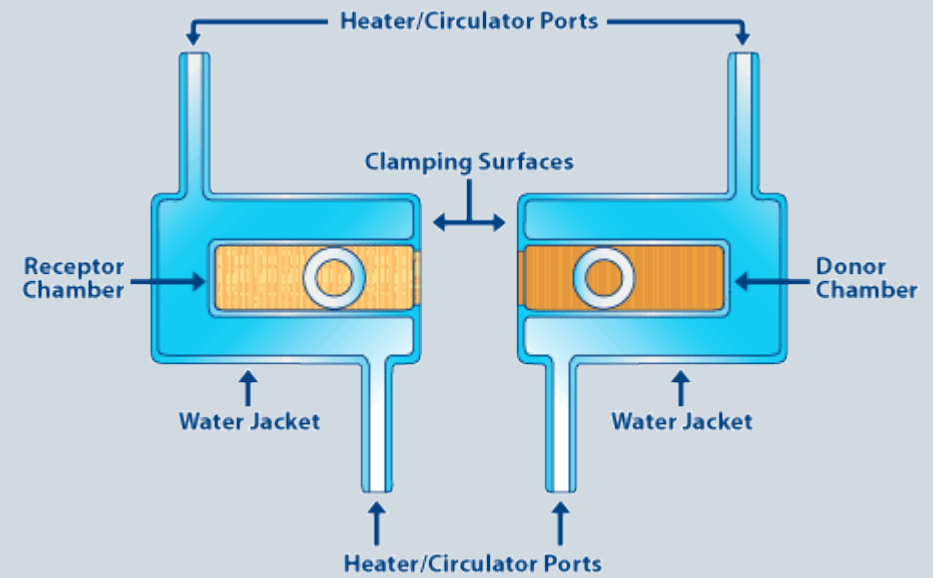


# Setup - Membrane Manufacturing





# Setup - Diffusion Cell



(Top-down view)

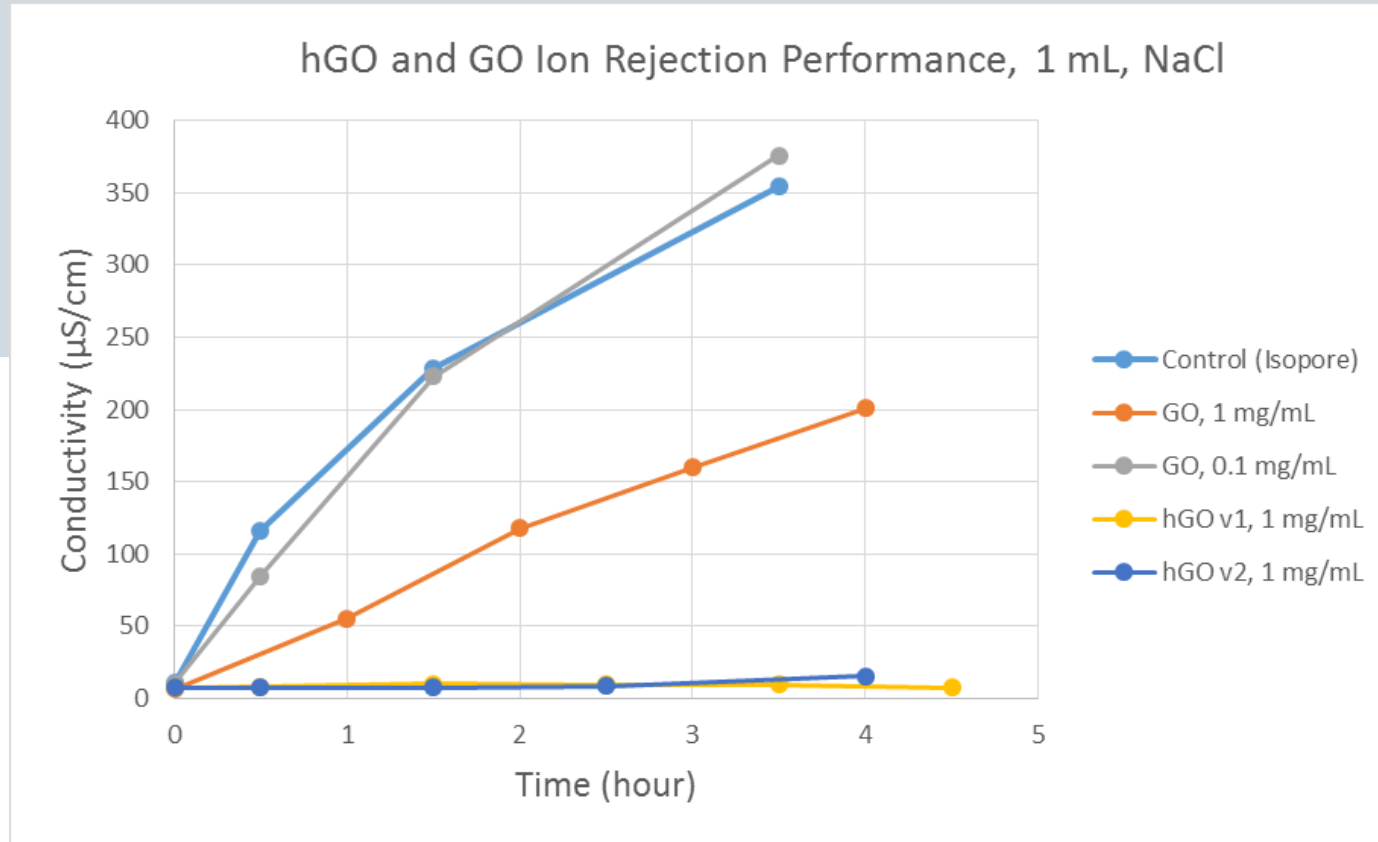
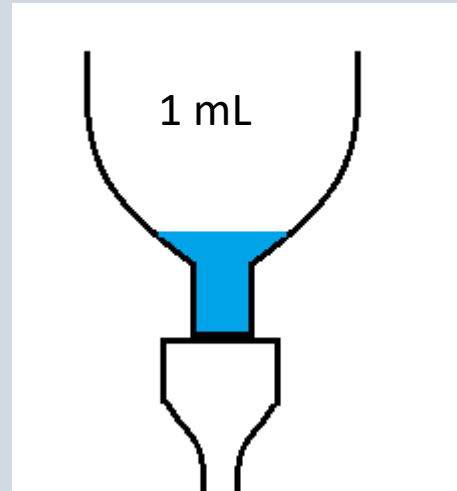
# Results – Overall Ion Rejection

GO Fared Worse

hGO v1 > hGO v2

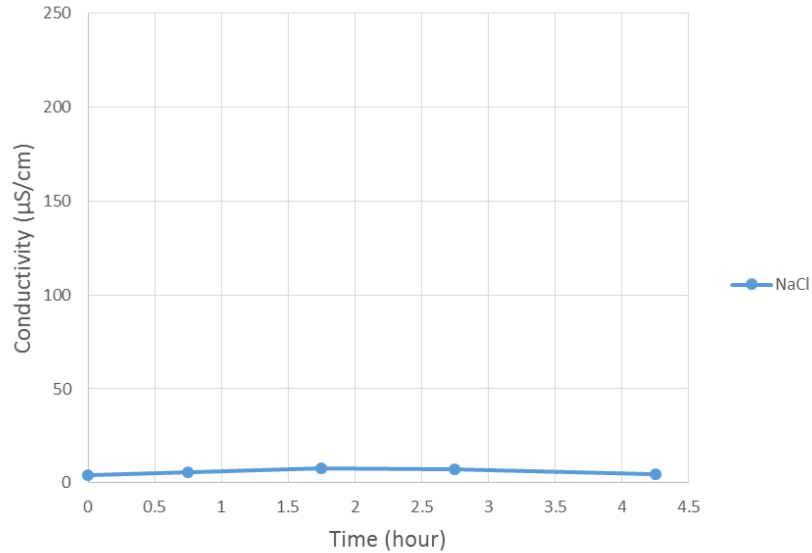
- v2 got worse

Move to Water Flux

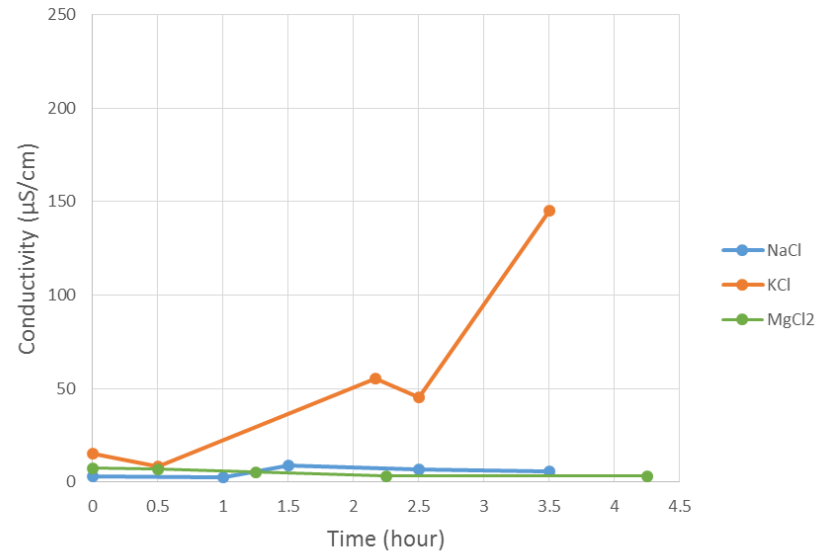


# Results - hGO v1 Ion Rejection

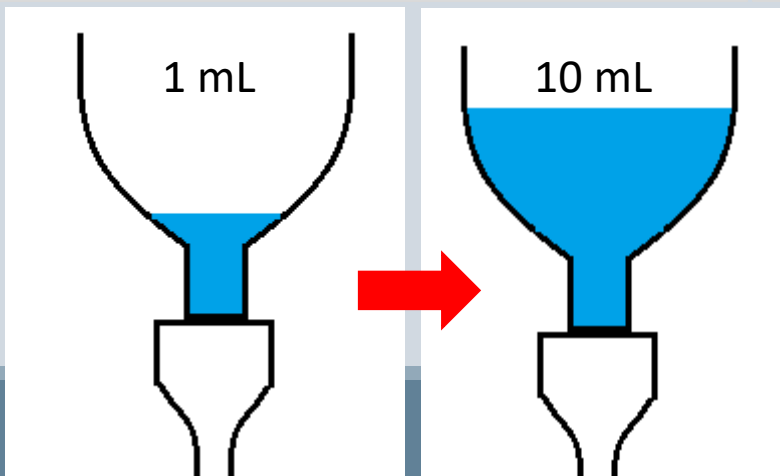
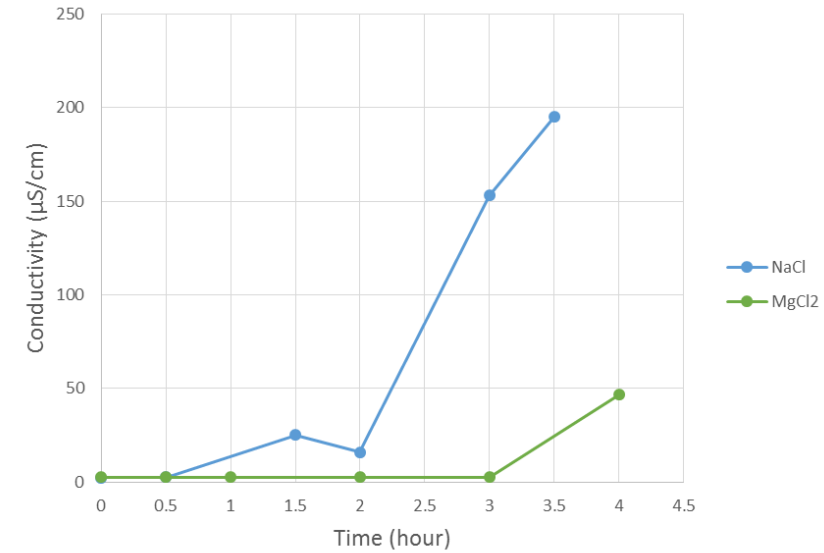
hGO v1, 0.1 mg/mL (10 mL)



hGO v1, 0.01 mg/mL (10 mL)

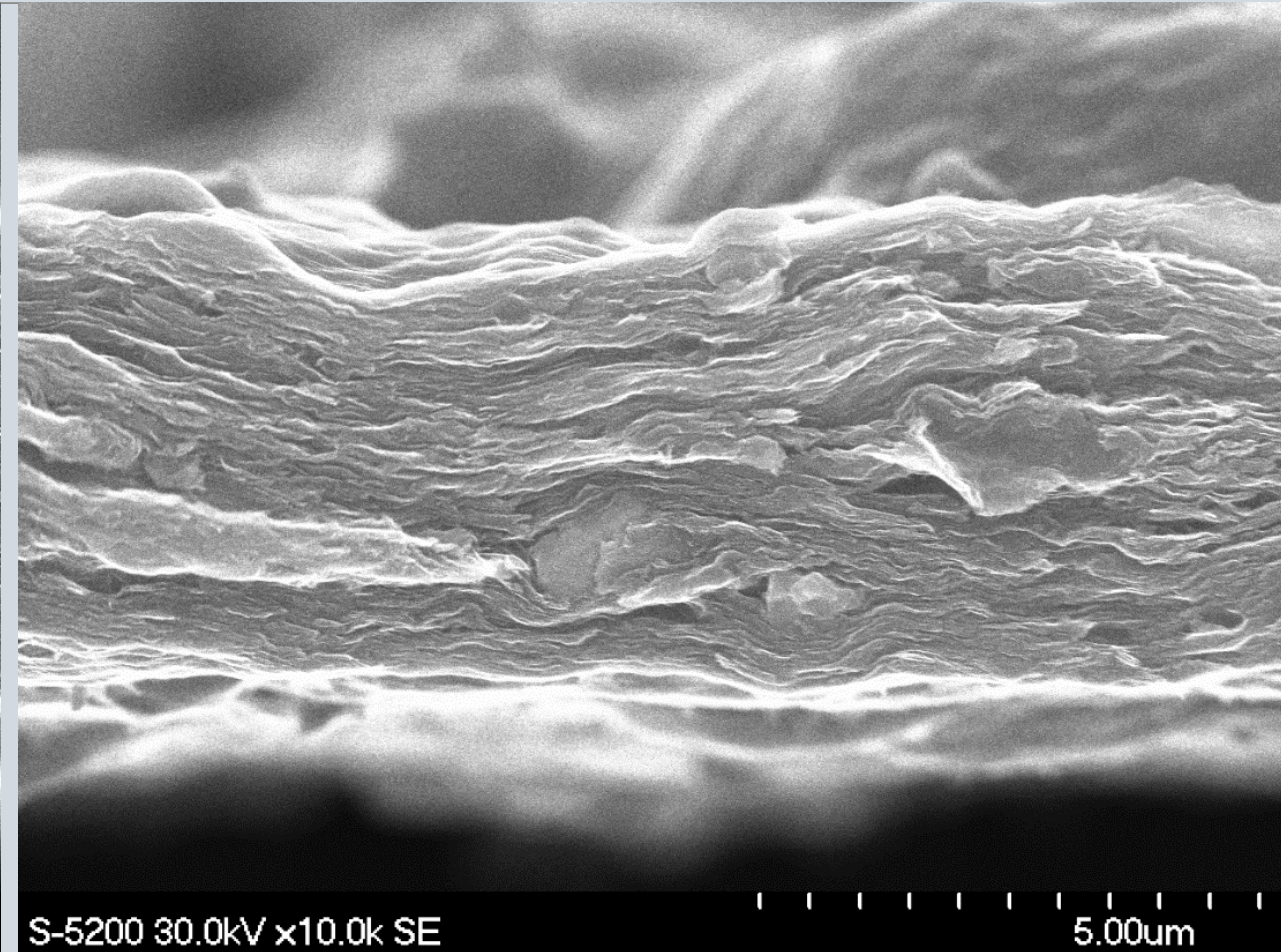
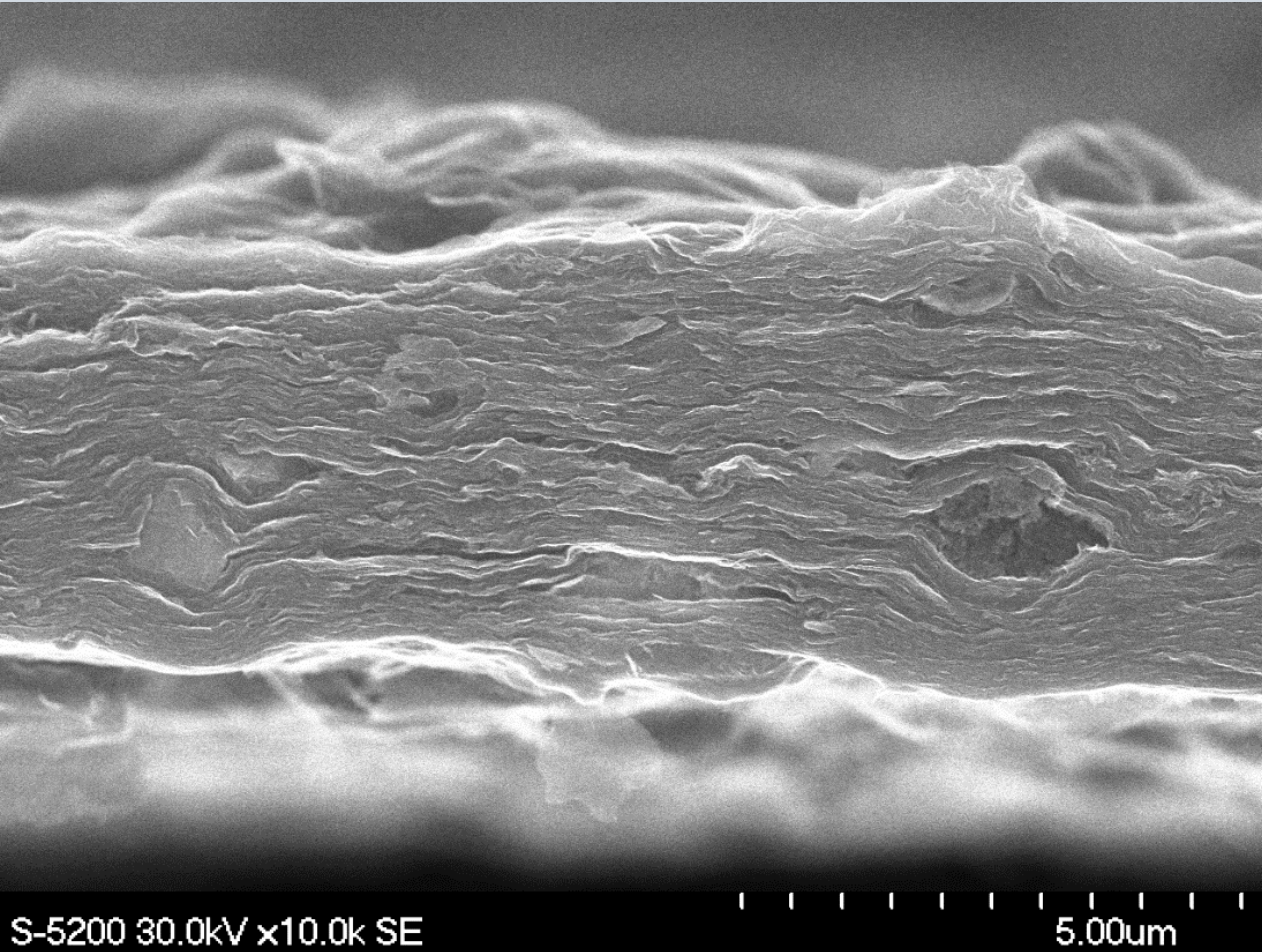


hGO v1, 0.001 mg/mL (10 mL)

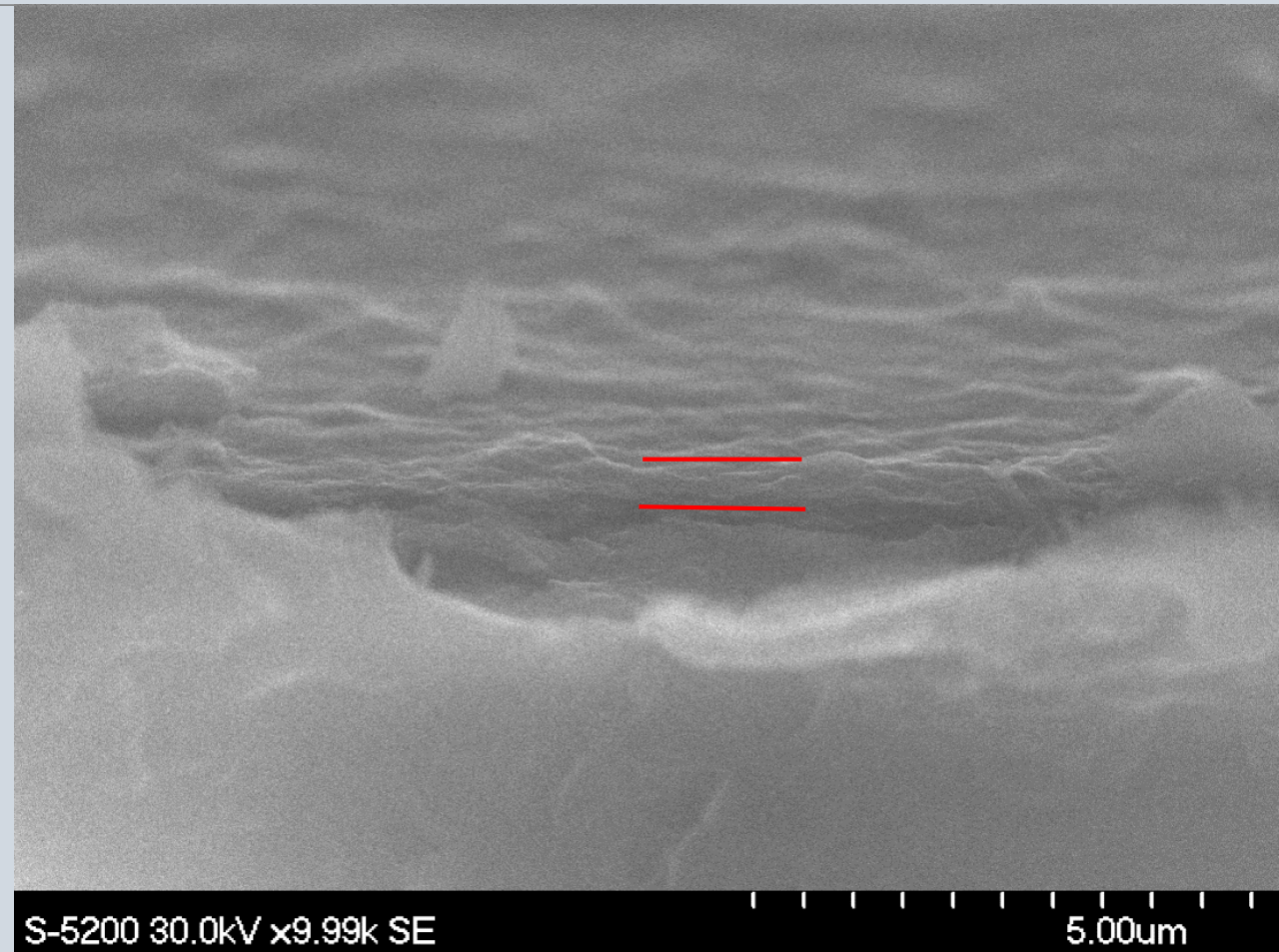
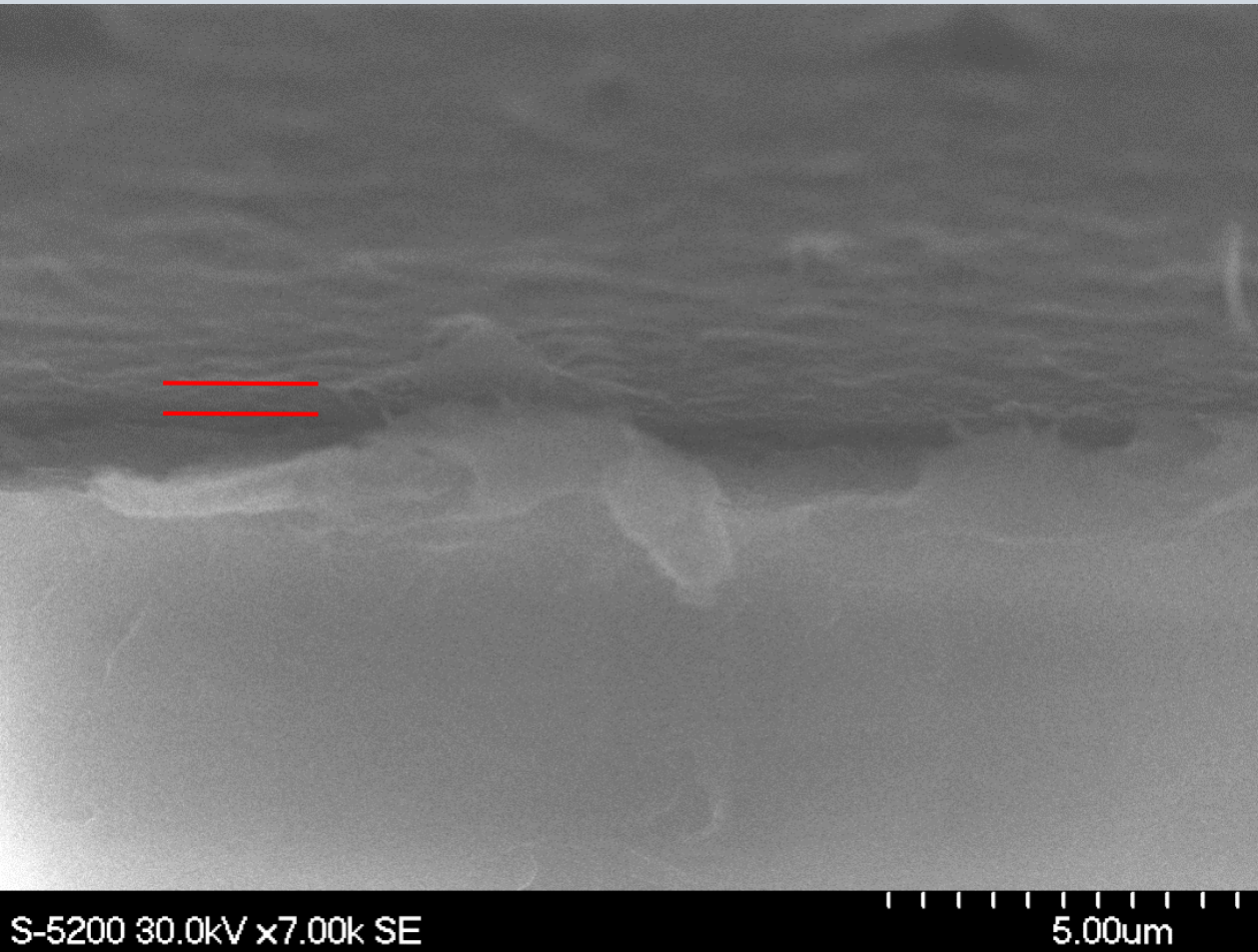


Ion	Hydrated Radius (nm)
Na <sup>+</sup>	0.358
K <sup>+</sup>	0.331
Mg <sup>2+</sup>	0.428
Cl <sup>-</sup>	0.332

# hGO v1, 0.1 mg/mL SEM Images

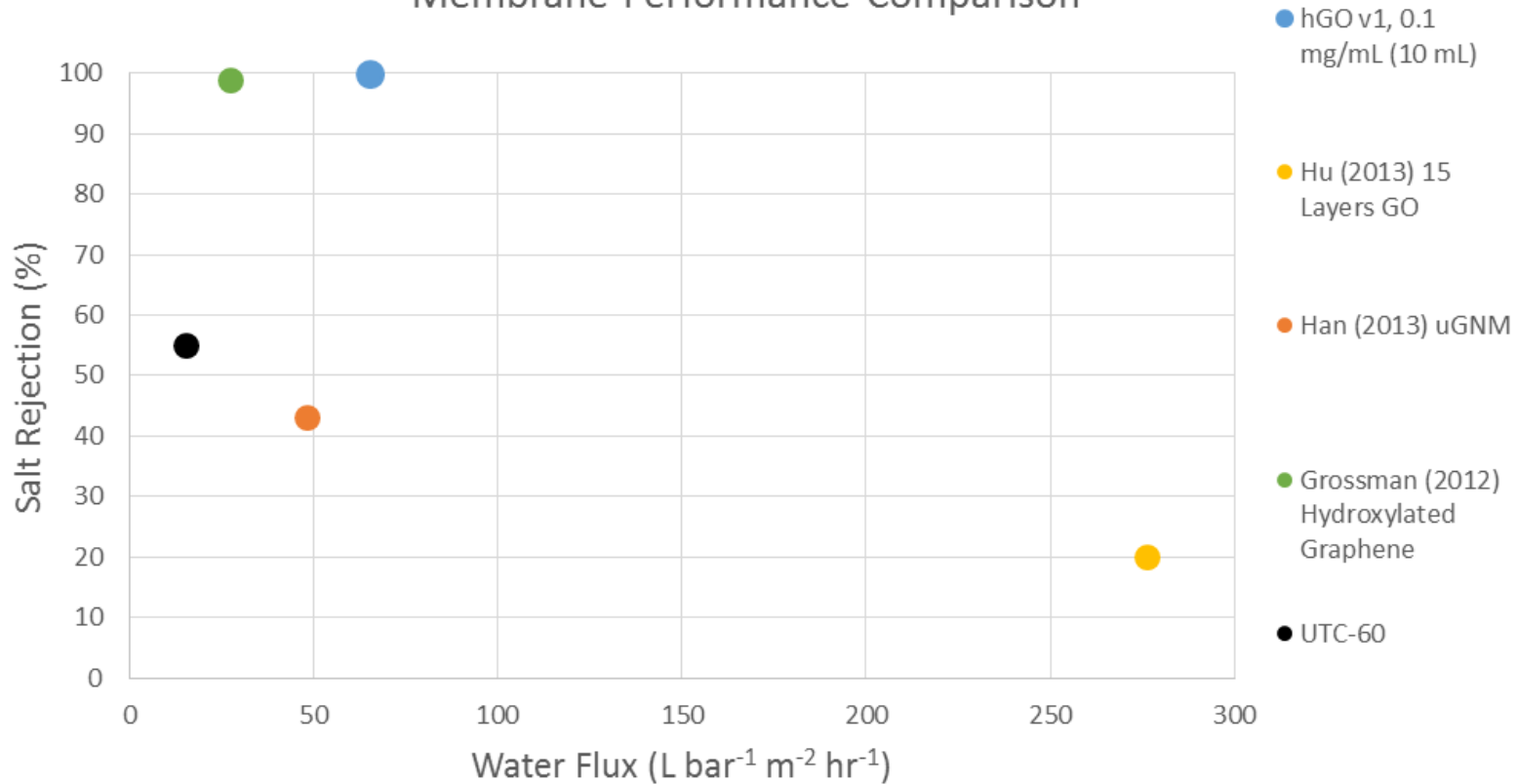


# hGO v1, 0.01 mg/mL SEM Images

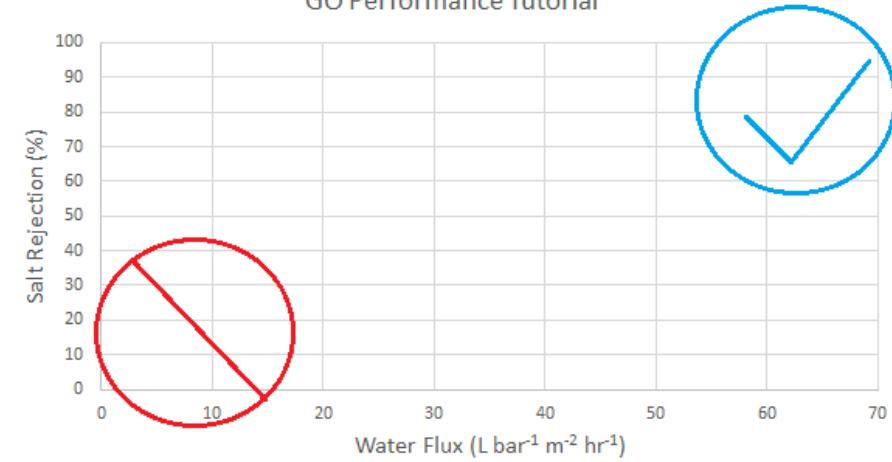


# Results - Ion Rejection vs. Water Flux

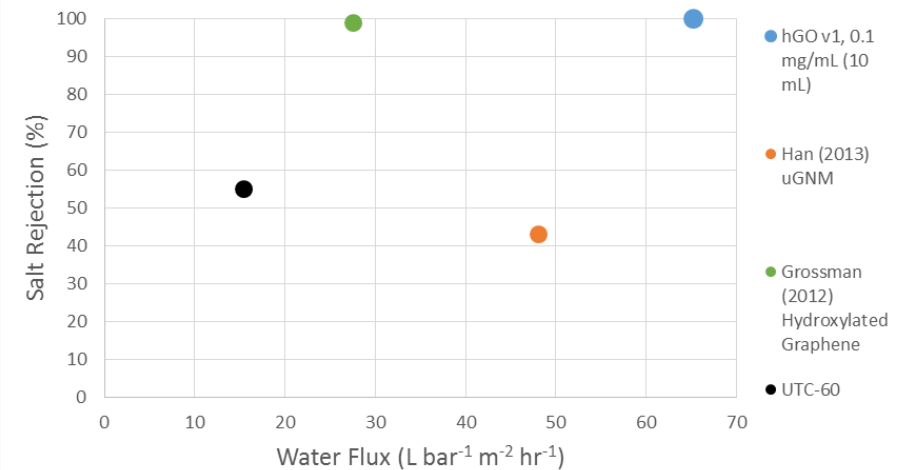
Membrane Performance Comparison



GO Performance Tutorial



Membrane Performance Comparison



# Going Forward

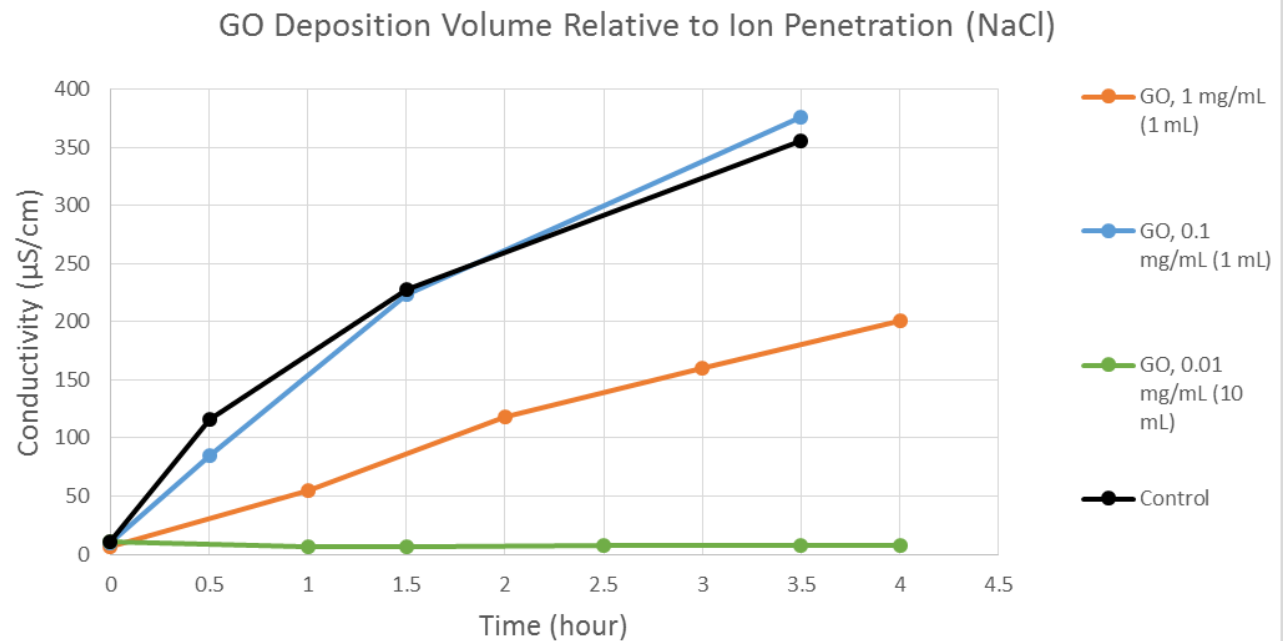
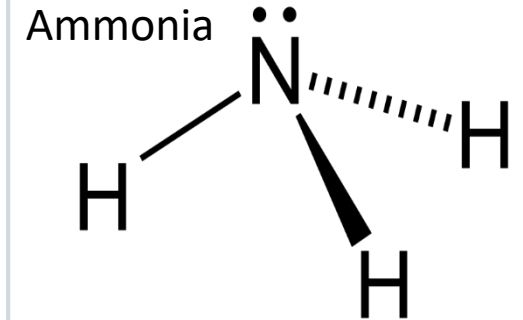
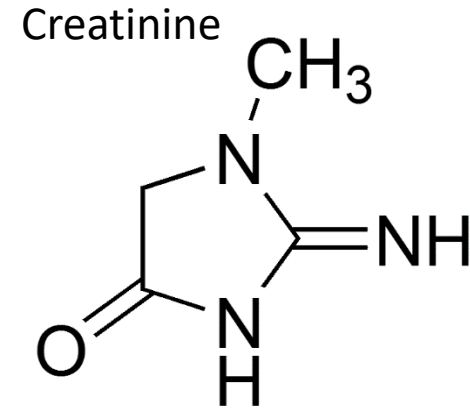
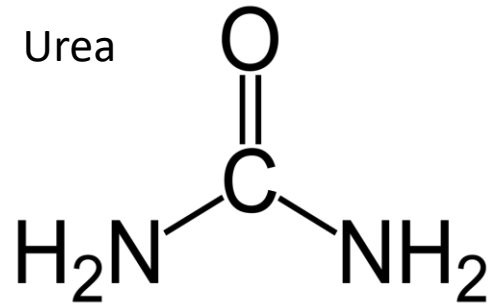
## Membrane Characterization

- Raman
- Goniometer

## Different Salts/Molecules

## Different Deposition Volumes

- 50 mL? 100 mL?



# Thank You!

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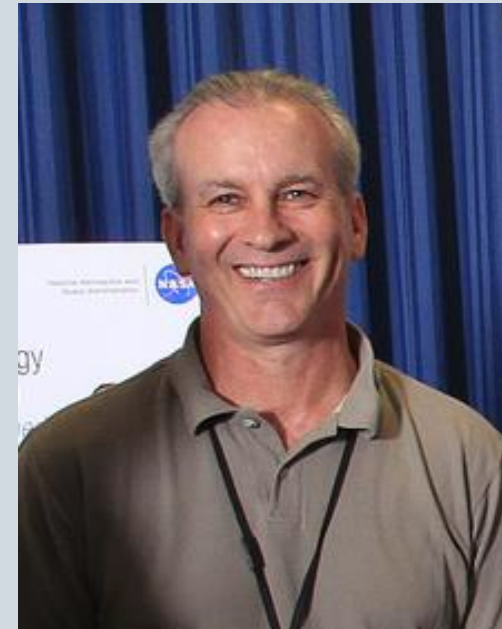
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North Dakota Space Grant Consortium

Dr. Yi Lin

Dr. John Connell





# References

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NASA Technology Roadmap

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Sun (2014) Selective Trans-Membrane Transport of Alkali and Alkaline Earth Cations through Graphene Oxide Membranes Based on Cation- $\pi$  Interactions