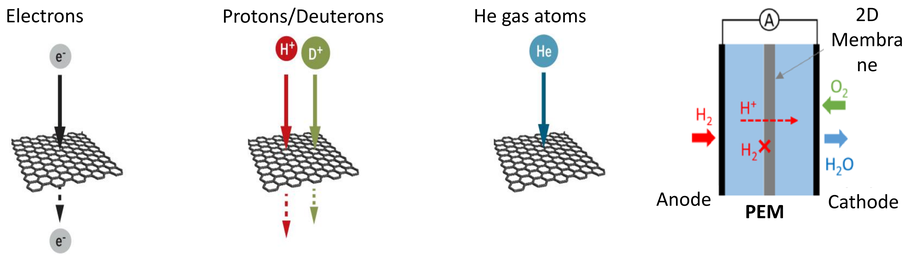
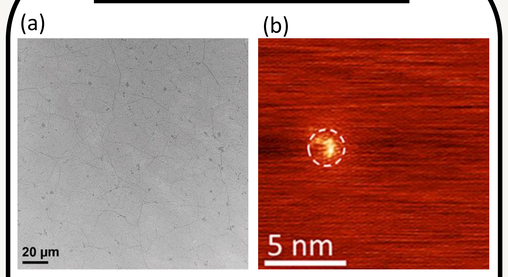
Parameter Space for Fabricating Atomically Thin Proton Exchange Membranes

Rahul Shah[1], Pavan Chaturvedi[2], Nicole Moehring[1,2], Piran R Kidambi[1,2]
[1]Interdisciplinary Material Science, Vanderbilt University, Nashville, TN, 37235, USA
[2]Chemical and Biomolecular Engineering Department, Vanderbilt University, Nashville, TN, 37212, USA

Graphene as a Selective Membrane



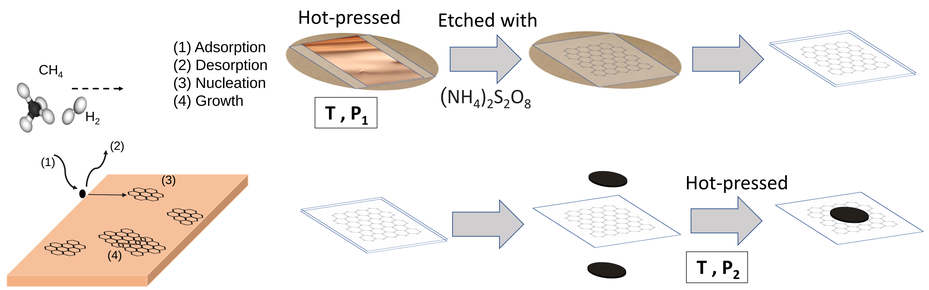
Why defects matter?



(a) SEM and (b) STM micrograph of Graphene grown on Cu (circle = atomic scale defect)

Ideal proton exchange membrane:
(1) high H^+ conductivity and **(2) low H_2 crossover**.
Surface defects can affect both these factors

Graphene Growth and Transfer

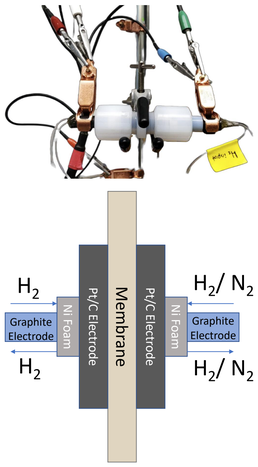


Schematic of steps of CVD growth of Graphene

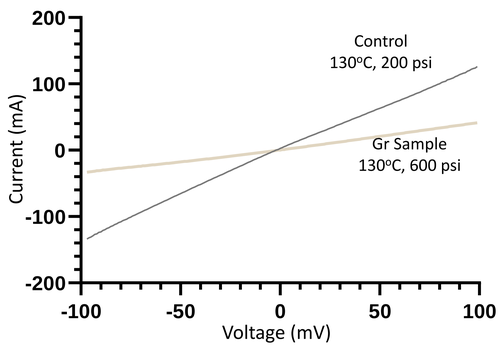
Top row: Graphene transfer from Cu film to Nafion membrane
Bottom row: Electrode pressing onto Nafion-Graphene-Nafion membrane

Proton Conductivity and H_2 Crossover Measurements through Graphene Membrane

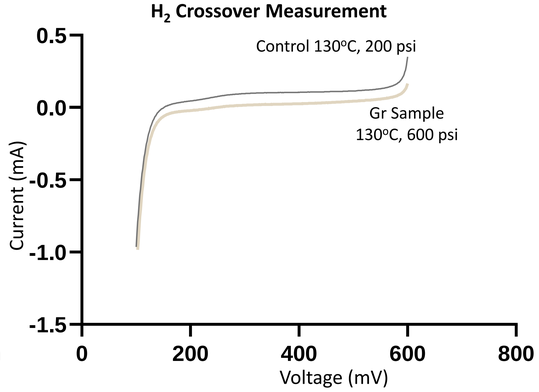
Homemade fuel cell setup



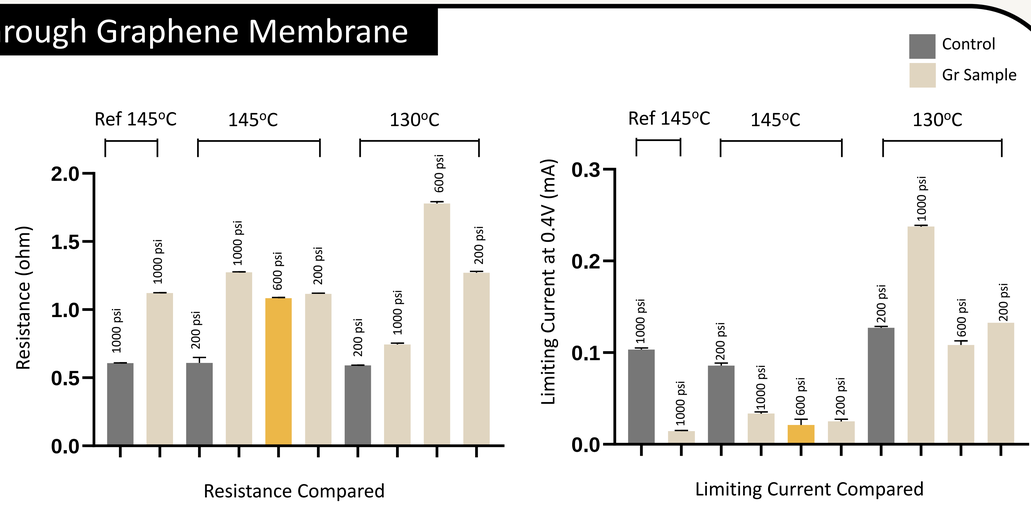
Membrane Assembly



Slope of I-C curve = H^+ Conductivity



Limiting Current = Crossover Current at 0.4V



Resistance Compared

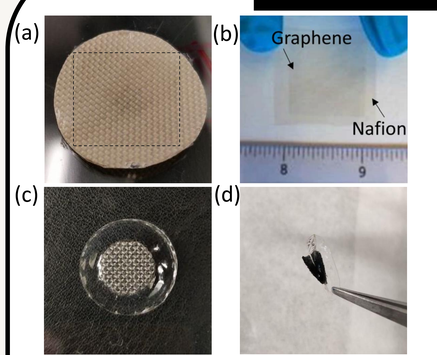
Limiting Current Compared

Parameters tested

T (°C) / P_1 (psi)	115	130	145
200	Electrode Delaminated ✖	✓	✓
600	Electrode Delaminated ✖	✓	★
1000	Electrode Delaminated ✖	✓	✓

Electrodes were pressed for all sample at the same T and P_2 = 200 psi

Conclusions



(a) Graphene transferred onto nafion on PTFE
(b) Graphene on Nafion
(c) Electrodes hot pressed onto membrane
(d) Electrodes delaminating from membrane.

Ideal proton exchange membrane = LOW resistance to H^+ transport, LOW H_2 crossover

Graphene transfer onto nafion successful at T = 115°C, 130°C and 145°C

Electrode pressing onto membrane failed at T = 115°C

Gas phase measurements show that pressing parameters influence surface defects

From the studied parameters, membrane fabricated with hot-press conditions of 145°C and 600 psi showed best performance

Acknowledgement

I would like to thank Prof. Piran Kidambi and all members of Kidambi Lab for their support and guidance during this 10-week rotation. Special thanks to Pavan and Nicole for being the best mentors.

Sincere appreciation for Prof. Josh Caldwell and Sarah Ross for their support during this first semester at the IMS program at Vanderbilt.

Thanks to VINSE for SEM imaging facility.

References

1. Kidambi, P.R. ,et al. Science 374, 708 (2021)
2. Peifu Cheng, et al. Nanoscale, **13**, 2825-2837 (2021)
3. Kidambi, P.R. ,et al. ACS Applied Materials & Interfaces 10 (12), 10369-10378 (2018)
4. Eoin Griffin, et al. ACS Nano 14 (6), 7280-7286 (2020)
5. Nicole K. Moehring, et al. ACS Nano 16 (10), 16003-16018 (2022)

rahul.shah.1@vanderbilt.edu