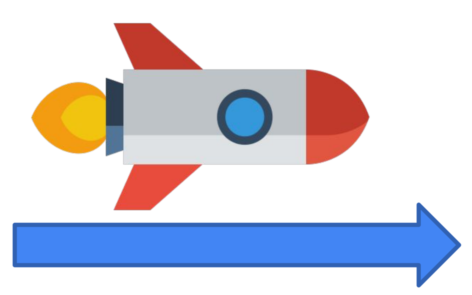
3D Printed Hydrodynamic Electrochemical Devices for Homeostasis monitoring

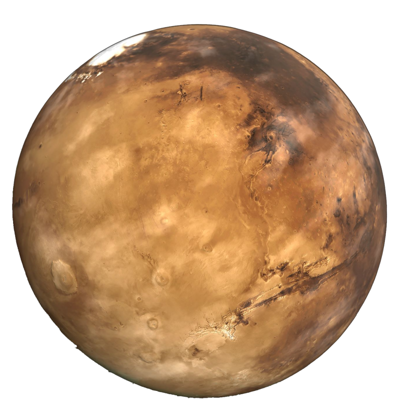
Edgar Manriquez, Robert Clark Jr., Steven Douglass, Elizabeth Peebles, Sebastian Quinn, Dr. Glen O'Neil
Montclair State University, Department of Chemistry, Montclair NJ, 07043

INTRODUCTION

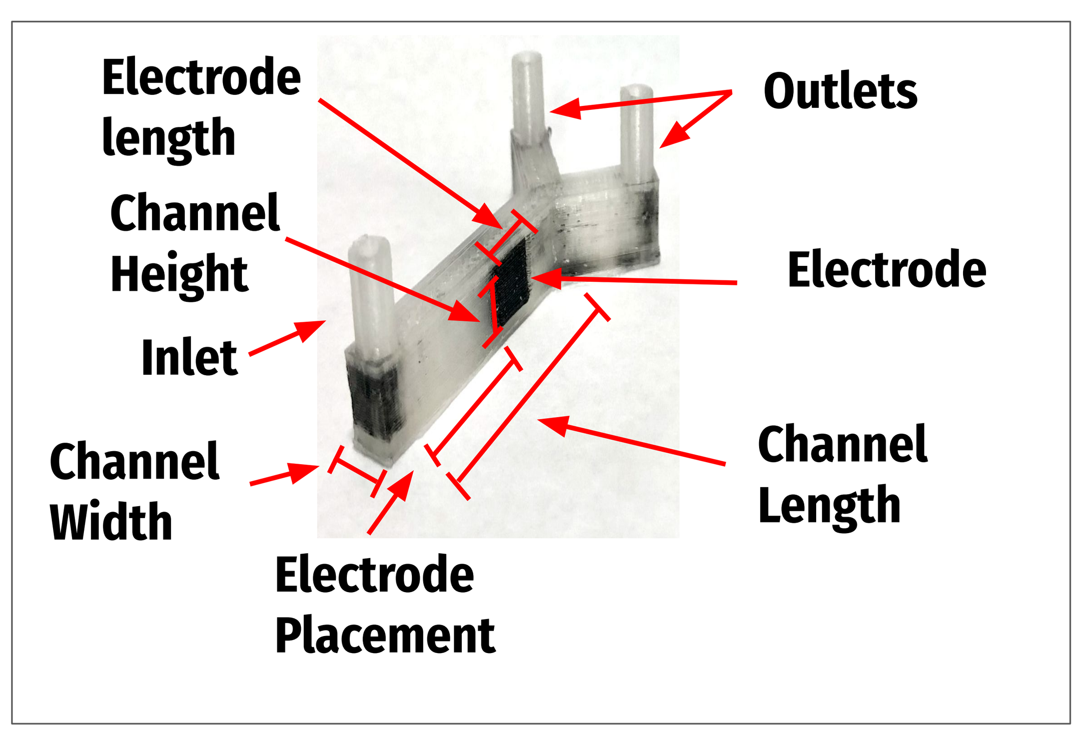
- 3D printing is a layer-by-layer fabrication method used for producing functional devices, sensors, and labware[1]
- We recently introduced a method for fabricating hydrodynamic electrochemical cells in a single step with multi-material 3D printing[2]
- 3D printing is advantageous for astronaut health monitoring because it allows a ground-based team to design, test, and verify sensors and devices, send the digital design file to a crew in space, where the device can be fabricated in situ with a 3D-printer.[3]
- The goal of this work is to design, fabricate, and characterize membraneless electrochemical devices suitable for electrosynthesis so that astronauts have a route to making life-sustaining chemicals during long-duration spaceflights



- 9 months
- Limited resources

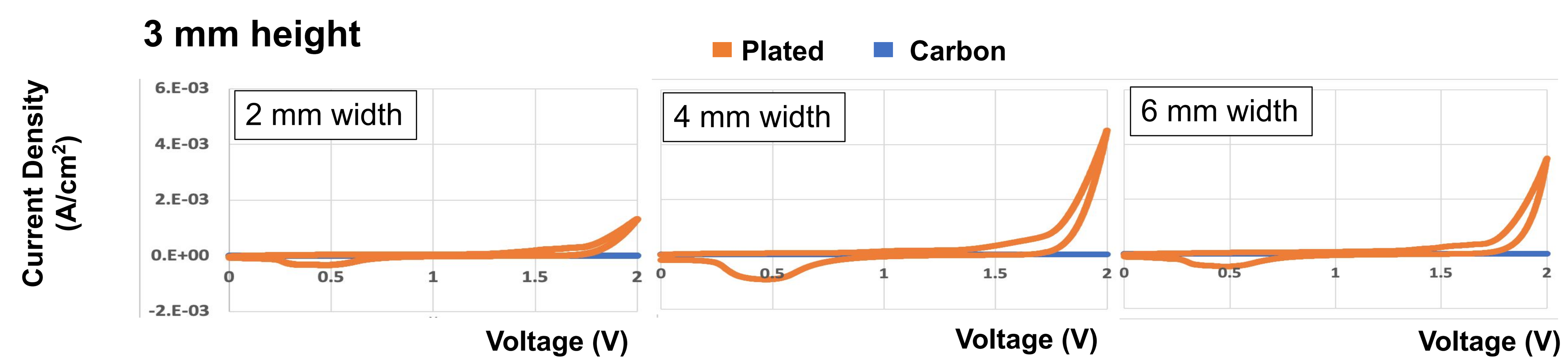


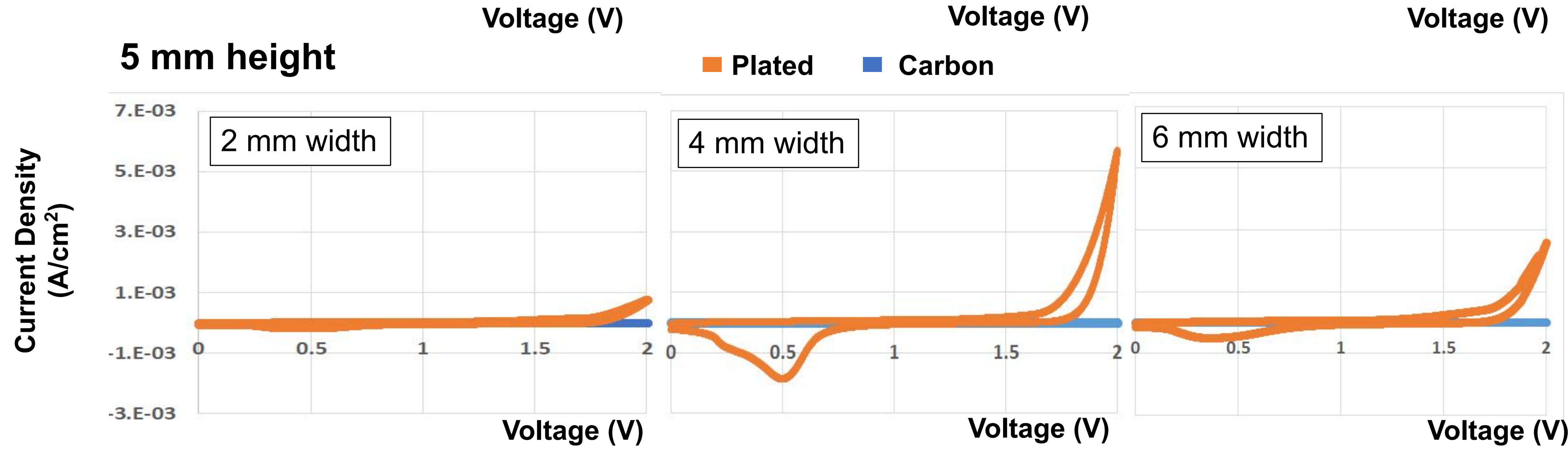
METHODS



- Devices were designed according to the schematic above.
- All devices were printed on an Ultimaker S3 using natural PLA (body) and conductive PLA (electrodes)
- Devices were modified using platinum catalysts and evaluated in 0.5 M H_2SO_4

IMPACT OF CHANNEL WIDTH ON PERFORMANCE





- Impact of channel geometry was evaluated using cyclic voltammetry in 0.5 M H_2SO_4
- Cathode reaction: $2H^+(aq) + 2e^-$ □ $H_2(g)$
- Anode reaction: $H_2O(l)$ □ $½O_2(g) + 2H^+(aq) + 2e^-$
- Overall reaction: $H_2O(l)$ □ $H_2(g) + 1/2O_2(g)$

- We used the measured current at 2 V as a proxy for amount of H_2 and O_2 produced.
- Larger current = most H_2 and O_2 produced

- In all cases, deposition of Pt catalysts demonstrated increased activity (shown as the blue trace versus the orange trace). *This highlights the need for post-fabrication modification of the electrodes.*
- For each channel height, the 4 mm channel had the largest current, followed by the 6 mm width, the 2 mm width.
- We expected the 2 mm device to have the highest current because is has the lowest solution resistance. *We hypothesize that gas crossover in the 2 mm wide channels lowered the device efficiency.*

- The best performing device was the 5 mm (height) x 4 mm (width)

REFERENCES

[1] M. Pumera, Three-dimensionally printed electrochemical systems for biomedical analytical applications. *Current Opinion in Electrochemistry* **2019**, doi: 10.1016/j.coelec.2019.02.001
[2] G.D. O'Neil, S. Ahmed, K. Halloran, J.N. Janusz, A. Rodríguez, I.M. Terrero Rodríguez, Single-step fabrication of electrochemical flow cells utilizing multi-material 3D printing. *Electrochem. Commun.* **2019**, *99*, 56-60.
[3] G.D. O'Neil. Towards Single-step Production of Functional Electrochemical Devices using 3D Printing: Progress, Challenges, and Opportunities. *Current Opinion in Electrochemistry* **2020**, *20*, 60-65.

PRELIMINARY GAS COLLECTION MEASUREMENTS

Experimental gas collection setup

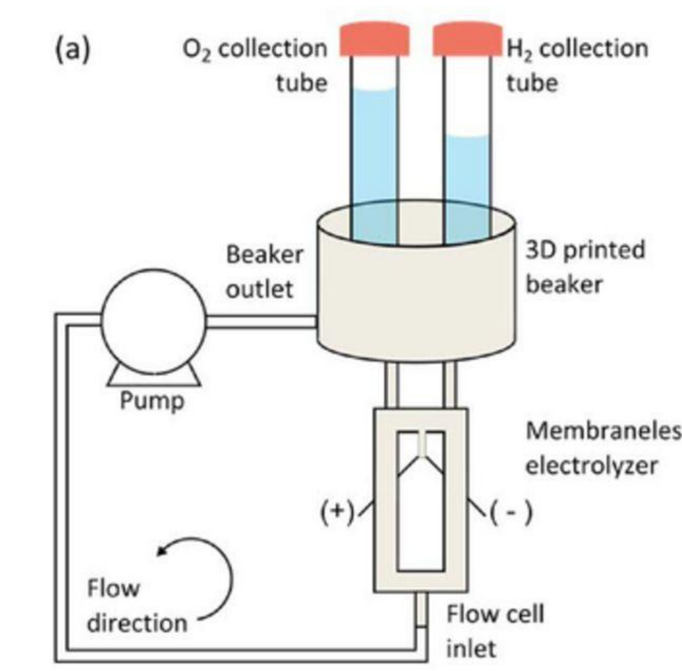


Image of collected gas in tubes

- Gas collection measurements were performed by running the device outlets into sealed, calibrated gas collection tubes.
- Volume of each gas could be measured and compared to predicted values based on reaction stoichiometry.
- Preliminary measurements showed a ~2:1 ratio of H_2 to O_2, as predicted by the overall reaction.

CONCLUSIONS AND FUTURE WORK

- Here we demonstrated that a 3D printed device can be used to perform the electrosynthesis of H_2 and O_2.
- When adjusting parameters we found that the efficiency of the device changed. Further testing will allow us to find the best parameter settings.
- Initial gas collection measurements showed a ~2:1 ratio of H_2 to O_2. Once gas can be collected faradaic efficiency can be calculated.
- Future work will require more robust gas collection measurements, analysis of product crossover using GC, and measurement of Faradaic efficiency.
- Use of more efficient catalysts for the oxygen evolution reaction – e.g., IrO_2 or RuO_2

ACKNOWLEDGEMENTS

- The NASA New Jersey Space Grant Consortium Summer Internships Program
- PSEG ISS Green Teams program at Montclair State University for additional support.