3D Printed Hydrodynamic Electrochemical Devices for Homeostasis monitoring

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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 evaluate in 0.5 M H$_2$SO$_4$ natural PLA (body) and conductive PLA (electrodes)

METHODS

• Devices were designed according to the schematic above.
• All devices were printed on an Ultimaker S3 using digital design file to a crew in space, where the device can be fabricated in situ with a 3D-printer.
• Devices were modified using platinum catalysts and evaluated in 0.5 M H$_2$SO$_4$

IMPACT OF CHANNEL WIDTH ON PERFORMANCE

• Impact of channel geometry was evaluated using cyclic voltammetry in 0.5 M H$_2$SO$_4$
• Cathode reaction: 2H$^+$ (aq) + 2e$^-$ $\rightarrow$ H$_2$(g)
• Anode reaction: H$_2$O(l) $\rightarrow$ $\frac{1}{2}$O$_2$(g) + 2H$^+$ (aq) + 2e$^-$
• Overall reaction: H$_2$O(l) $\rightarrow$ H$_2$(g) + $\frac{1}{2}$O$_2$(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


PRELIMINARY GAS COLLECTION MEASUREMENTS

• 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 electrolysisis 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$_2$

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