Hawaiʻi Natural Energy Institute Research Highlights

Electrochemical Power Systems

Contaminant Tolerant Fuel Cells for Harsh Environments

<u>OBJECTIVE AND SIGNIFICANCE</u>: Fuel cells offer the opportunity to significantly increase the flight duration of electric powered unmanned aerial vehicles (UAVs). With fuel cell power systems, increases of 5-10x in flight duration are possible for the same volume and weight constraints as high energy lithium batteries. Under this task, HNEI continued support to the Naval Research Laboratory's (NRL) efforts to develop lightweight, high efficiency fuel cell systems for UAVs including developing components that enhance contaminant tolerance. Contamination mechanisms in proton exchange membrane (PEM) fuel cells can become quite complex with many sources (air, fuel, system materials) and problems can be compounded by the contaminant reaction products that impact many key fuel cell materials.

<u>BACKGROUND</u>: A partnership between HNEI and NRL was established in 2009 to aid in NRL's development of the IonTiger UAV using a fuel cell made by an outside vendor. This NRL program resulted in an unofficial world-record fuel cell powered UAV flight of 26 hours on compressed hydrogen, and later 48 hours using an NRL-developed, cryogenic hydrogen storage system. Subsequently, NRL has continued to develop their own proprietary fuel cells and systems for UAV applications. HNEI has supported this effort, and continues to support this effort, via diagnostic testing, evaluation of needs, and design recommendations.

More recently, HNEI has shifted focus from testing support and is currently working on the design, development, and demonstration of PEM fuel cell components that enhance contaminant tolerance at elevated operating temperatures. Most industry wide efforts in contamination to date have primarily focused on low temperature (60-90°C) PEM fuel cells for transportation and unmanned vehicle applications. High temperature (140-200°C) PEM (HTPEM) fuel cells have the benefits of higher contaminant tolerance and lower cost membranes vs. low temperature PEM fuel cells. Additionally, the higher operating temperatures can help reduce the system complexity and provide opportunities for volume reduction, e.g. heat exchanger size reduction, a major consideration for use of fuel cells for small UAVs (1-10 kW).

<u>PROJECT STATUS/RESULTS</u>: Under this work, HNEI has established a fabrication system (Figure 1) originally developed by NRL for creating custom catalyst coated membranes for small UAV scale fuel cells based on ultrasonic spray deposition and is adapting the NRL protocol to work with high temperature materials with improved contamination resistance. The ability to create custom catalyst coated membranes (CCMs) is an essential capability in the research and development of advanced electrocatalysts, gas diffusion media (GDM), ionomers, polymer electrolyte membranes (PEMs), and electrode structures designed for use in next-generation contaminant resistant fuel cells for UAVs.

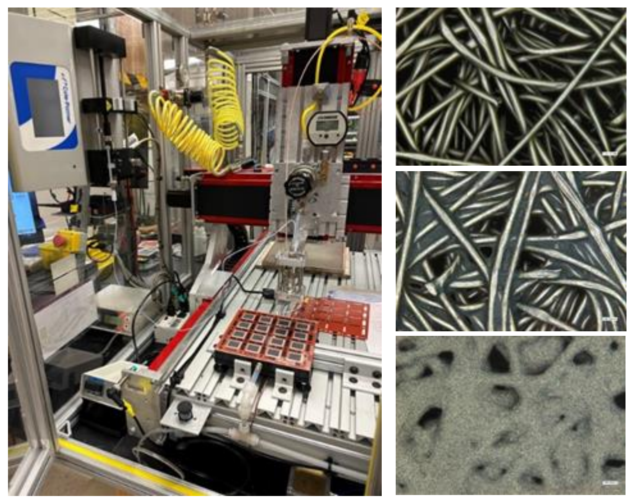

Figure 1. Upgraded spray coating system (left) for producing new HTPEM electrodes and laser confocal scans showing variety of depositions performed (right, top) bare carbon paper (right, middle) PTFE deposition (right, bottom) catalyst layer deposition.

To date, we have established a multi-electrode fabrication approach to produce up to 16 electrodes in one deposition run. HNEI also initiated performance evaluations of in-house fabricated electrodes and began planning for in-situ contaminant tolerance evaluations to be initiated in early 2025.

This work has resulted in the publications and presentations listed on the following page.

Funding Source: Office of Naval Research

Contact: Keith Bethune, bethune@hawaii.edu

Last Updated: November 2024

ADDITIONAL PROJECT RELATED LINKS

PAPERS AND PROCEEDINGS:

1. 2020, K. Bethune, J. St-Pierre, J.M. LaManna, D.S. Hussey, and D.L. Jacobson, **Contamination Mechanisms of Proton Exchange Membrane Fuel Cells-Mass Transfer Overpotential Origin**, The Journal of Physical Chemistry C, Vol.124, Issue 44, pp. 24052-24065.
2. 2020, Y. Garsany, C.H. Bancroft, R.W. Atkinson III, K. Bethune, B.D. Gould, K.E. Swider-Lyons, **Effect of GDM Pairing on PEMFC Performance in Flow-Through and Dead-Ended Anode Mode**, Molecules, Vol. 25, Issue 6, Paper 1469. (Open Access: **PDF**)
3. 2015, B.D. Gould, J.A. Rodgers, M. Schuette, K. Bethune, S. Louis, R. Rocheleau, K. Swider-Lyons, **Performance and Limitations of 3D-Printed Bipolar Plates in Fuel Cells**, ECS Journal of Solid State Science and Technology, Vol. 4, Issue 4, pp. P3063-P3068. (Open Access: **PDF**)

PRESENTATIONS:

1. 2022, Y. Garsany, R. E. Carter, M.B. Sassin, K. Bethune, and B. Gould, **Pairing Gas Diffusion Media for High-Power PEMFC Operation,** Presented at the ECS 2022-02 Meeting, Atlanta, Georgia, October 9-13, Abstract 1380.
2. 2020, Y. Garsany, C.H. Bancroft, R.W. Atkinson, K. Bethune, B.D. Gould, K. Swider-Lyons, **Operation of PEMFC Anodes in Dead-Ended Vs. Flow-through Modes**, Presented at the ECS 2020-02 Meeting, Honolulu, Hawaiʻi, October 4-9, Abstract 2212.
3. 2019, Y. Garsany, R.W. Atkinson, K. Bethune, J. St-Pierre, B.D. Gould, K. Swider-Lyons, **Cathode Catalyst Layer Design with Graded Porous Structure for Proton Exchange Membrane Fuel Cells**, Presented at the ECS 2019-02 Meeting, Atlanta, Georgia, October 13-17, Abstract 1423.