Hawaiʻi Natural Energy Institute Research Highlights

Electrochemical Power Systems

Fuel Cell Development for Electric Powered Unmanned Aerial Vehicles

OBJECTIVE AND SIGNIFICANCE: 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.

BACKGROUND: Electric propulsion offers several advantages over small hydrocarbon powered engines (e.g. near silent operation, instant starting, increased reliability, easier power control, reduced thermal signature, reduced vibration, and no electric generators). 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 (LTPEM) 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).

Under this work, HNEI is establishing a fabrication system (Figure 1) based on the NRL design to enable in-house fabrication of custom catalyst coated membranes. The objective is to adapt the NRL protocol to work with high temperature materials with inherent 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.

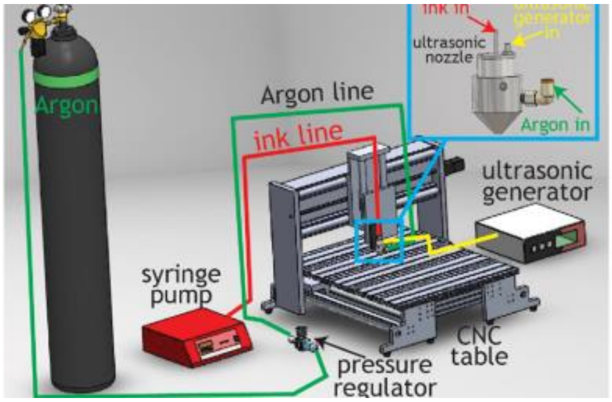

Figure 1. Ultrasonic spray coating system for in-house manufacturing of custom CCMs (insert).

PROJECT STATUS/RESULTS: HNEI has acquired equipment to establish capabilities to manufacture membrane electrode assemblies in-house to support the development of HTPEM components. Anticipated completion of the equipment installation and laboratory modifications is expected in early 2022. For additional information, refer to the publication listing on the following page.

Funding Source: Office of Naval Research

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ADDITIONAL PROJECT RELATED LINKS

TECHNICAL REPORTS:

1. 2019, K. Bethune, **Support to NRL**, subsection of Task 2.1 Fuel Cell Testing, in ***APRISES 14 Final Technical Report***, Office of Naval Research Grant Award Number N00014-15-1-0028.
2. 2018, K. Bethune, **Support to NRL**, subsection of Task 2.1a Fuel Cell Development, in ***APRISES 12 Final Technical Report***, Office of Naval Research Grant Award Number N00014-13-1-0463.
3. 2018, K. Bethune, **NRL Support**, subsection of Task 2.1 Fuel Cell Development, Testing and Modeling, in ***APRISES 13 Final Technical Report***, Office of Naval Research Grant Award Number N00014-14-1-0054.

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. 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, Hawai'i, October 4-9, Abstract 2212.
2. 2019, R.W. Atkinson, Y. Garsany, K. Bethune, J. St-Pierre, B.D. Gould, K. Swider-Lyons, **Pairing Asymmetric Gas Diffusion Media for High-Power Fuel Cell Operation**, Presented at the ECS 2019-02 Meeting, Atlanta, Georgia, October 13-17, Abstract 1428.
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.