Fuel Cell Contamination

Hawaiʻi Natural Energy Institute

The Hawaiʻi Natural Energy Institute (HNEI) is conducting a comprehensive investigation of the impact of fuel, airborne and system contaminants on the performance of proton exchange membrane fuel cells (PEMFCs). In addition to contributing to the fundamental understanding of the degradation mechanisms for a variety of contaminants, HNEI is seeking to develop preventive as well as performance recovery procedures.

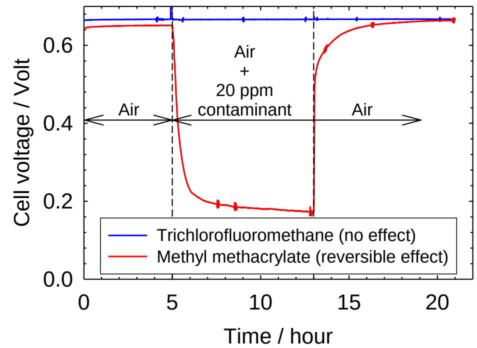

Figure 1. PEMFC performance transients.

Challenge & Significance

The development and deployment of electric vehicles, including fuel cell powered vehicles, offers the opportunity to radically alter the transportation sector. If produced from renewable sources, hydrogen for fuel cell powered vehicles can substantially reduce the use of fossil fuels. A number of car manufacturers in the US and elsewhere are heavily invested in the development of energy efficient and environmentally friendly PEMFC powered vehicles. While PEMFCs are projected to operate for 5,000 hours or more, this target has not been reached, partly due to the impacts of contaminants. Laboratory testing has shown that some of these contaminants progressively decrease cell performance, even at concentrations as low as parts per million (Figure 1). Contaminants originate from multiple sources and most have not been characterized, which increases risks associated with PEMFC commercialization efforts, particularly in urban areas affected by dense smog. HNEI's efforts reduce these risks by focusing on the identification of the most deleterious contaminants and finding ways to prevent or recover fuel cell damage.

Status & Accomplishments

- Developed extensive test capabilities to characterize the effects of contaminants on PEMFCs performance
  - High precision gas analysis
  - Multiple configuration hydrogen flow system for contamination accumulation studies
  - Tracer system for *in situ* product liquid water determination (under development)
- Compiled a database of characterization results for 29 different fuel, airborne and fuel cell system contaminants (Table 1)
- Developed a procedure to identify the most critical contaminants from a list of several hundred
- Contributed to the development of the International Organization for Standardization hydrogen fuel product specification (ISO 14687-2)
- Established PEMFC tolerance limits for 8 airborne contaminants (7 organic and 1 positive ion species)

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Partner(s):

- Naval Research Laboratory
- University of Connecticut
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Project Detail

Fuel cell contaminants originate from four main sources. Contaminants in air stem from both natural and anthropogenic (combustion and chemical industry) processes. Contaminants are also introduced in the fuel as a result of production and handling. PEMFC system construction materials can also release contaminants upon contact with liquid water. The use of cleansers on PEMFC system components can also leave residues containing contaminants.

Table 1. Contaminants studied at HiSERF

Airborne contaminants	Methyl tert-butyl ether
1,1-difluoroethane	Naphthalene
1,1,1,2-tetrafluoroethane	Nitrogen dioxide
2,2-bis(4-hydroxyphenyl)propane	Ozone
Acetaldehyde	Propene
Acetone	Sulfur dioxide
Acetonitrile	Toluene
Acetylene	Trichlorofluoromethane
Benzene	Vinyl acetate
Bromomethane	**Fuel contaminants**
Butane	Carbon monoxide
Calcium	Methyl cyclohexane
Chlorobenzene	Toluene
Dichloromethane	**System contaminants**
Iso-propanol	1-aza-2-cycloheptanone
Methyl acetate	Ethylene glycol
Methyl methacrylate	

The effect of contaminants significantly varies with operating conditions and fuel cell design. Thus, characterization tests were performed at the single cell, stack and system levels and with a wide range of operating conditions such as temperature and current density to gain a better understanding of contaminant impacts and facilitate the derivation of mitigation strategies. The contaminant concentration is an especially important operating condition as it is used to guide the development of specifications and tolerance limits (preventive measures). A more detailed characterization of contaminant effects was also carried out with both *in situ* and *ex situ* techniques to identify fuel cell materials that are affected as well as detect chemical and electrochemical reaction intermediates and products involving contaminants. These detailed studies are necessary to establish the mechanisms of contamination and subsequently devise more effective recovery procedures based on this fundamental knowledge.

Key Reports and Publications

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- J. St-Pierre, M. Angelo, K. Bethune, J. Ge, S. Higgins, T. Reshetenko, M. Virji, Y. Zhai, *Electrochem. Soc. Trans.*, **61** (23) (2014) 1.
- J. Ge, J. St-Pierre, Y. Zhai, *Electrochim. Acta*, **138** (2014) 437.
- Y. Garsany, J. Ge, J. St-Pierre, R. Rocheleau, K. E. Swider-Lyons, *J. Electrochem. Soc.*, **161** (2014) F628.
- J. St-Pierre, Y. Zhai, M. S. Angelo, *J. Electrochem. Soc.*, **161** (2014) F280 and *J. Electrochem. Soc.*, **162** (2015) X7.
- J. St-Pierre, B. Wetton, Y. Zhai, J. Ge, *J. Electrochem. Soc.*, **161** (2014) E3357.
- T. V. Reshetenko, K. Bethune, M. A. Rubio, Richard Rocheleau, *J. Power Sources*, **269** (2014) 344.
- B. D. Gould, G. Bender, K. Bethune, S. Dorn, O. A. Baturina, R. Rocheleau, K. E. Swider-Lyons, *J. Electrochem. Soc.*, **157** (2010) B1569.
- G. Bender, M. Angelo, K. Bethune, S. Dorn, T. Thampan, R. Rocheleau, *J. Power Sources*, **193** (2009) 713.

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