V.K.3 Effects of Fuel and Air Impurities on PEM Fuel Cell Performance

Fernando H. Garzon (Primary Contact), Idoia G. Urdampilleta, Tommy Q. T. Rockward, Eric L. Brosha, and Francisco A. Uribe
Los Alamos National Laboratory
MPA-11, MS. D429
Los Alamos, NM 87545
Phone: (505) 667-6643; Fax: (505) 665-4292
E-mail: garzon@lanl.gov

DOE Technology Development Manager: Kathi Epping
Phone: (202) 586-7425; Fax: (202) 586-9811
E-mail: Kathi.Epping@ee.doe.gov

Technical Advisor: John Kopasz
Phone: (630) 252-7531; Fax: (630) 972-4405
E-mail: kopasz@cmt.anl.gov

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Project End Date: October 2009

Objectives

- Test fuel cell performance using a simulated multi-component hydrogen impurity gas mixture.
- Investigate effects of impurities on catalysts and other fuel cell (FC) components.
- Understand the effect of catalyst loadings on impurity tolerance.
- Investigate the impacts of impurities on catalyst durability.
- Develop methods to mitigate negative effects of impurities.
- Develop models of FC-impurity interactions.
- Determine impurity tolerance limits in view of the technical targets for catalyst loading, performance and durability.
- Provide experimental data to hydrogen suppliers for defining fuel specifications.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan (MYRDDP):

(A) Durability
(B) Cost
(C) Performance

Technical Targets

TABLE 1. Technical Targets: Electrocatalysts for Transportation Applications (Extracted from Table 3.4.12 of the MYRDDP, April 27, 2007)

Characteristic	Units	2005 Status		Stack Targets	
		Cell	Stack	2010	2015
Platinum group metal total content (both electrodes)	g/kW (rated)	0.6	1.1	0.3	0.2
Platinum group metal (PGM) total loading	mg PGM/cm^2 electrode area	0.45	0.8	0.3	0.2

The technical targets in term of catalyst loading are indicated in Table 1. These targets were formulated on the assumption of FC operation with pure hydrogen fuel and air. One of the specific goals of this project is to determine, from experimental data, the limits of impurity tolerance within those technical targets. The results of this project will provide data for defining the FC hydrogen fuel specifications and air quality. Some of these results are shown in the Accomplishments section.

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Approach

During this period, our research has been focused on the effects of a fuel impurity mixture containing H_2S, NH_3, CO, CO_2 and ethylene on FC performance [1]. The effects of this mixture were tested on cells containing various Pt catalyst loadings. The loadings corresponded to the DOE targets of years 2005 and 2010.

The study also included the effects of H_2S concentration and FC operating conditions (such cell voltage and relative humidity) on H_2S tolerance. Elucidation of the H_2S poisoning mechanism was carried out using chemical analysis and electrochemical methods.

Accomplishments

- Tested several cells with the FreedomCAR hydrogen fuel specification (see Table 2).
- Demonstrated that decreasing the fuel cell anode loading (from 0.2 to 0.06 mg Pt/cm^2) is not having a great impact on the performance degradation behavior of polymer electrode membrane (PEM) FCs (see Figure 1).

- Verified that sulfur species adsorb very strongly on Pt for a wide range of potentials and concentrations.
- Found that for a given total exposure to H_2S, the higher the impurity concentration the more severe the performance degradation (see Figure 2).
- Demonstrated that H_2S tolerance depends on relative humidity of the fuel mixture (see Figure 3). The dryer the mixture the faster the degradation.
- Found that impurity crossover from anode to cathode needs to be considered; hydrogen sulfide crossover from anode to cathode may be occurring.
- Established that trace impurity effects may affect the oxidation reduction reaction (ORR) at the cathode.

Special Recognitions & Awards/Patents Issued

1. F. Uribe and T. Rockward, "Cleaning (de-poisoning) PEMFC electrodes from strongly adsorbed species on the catalyst surface", 104229 Non-Provisional patent application. (2006).

TABLE 2. FreedomCAR Hydrogen Fuel Specification

Component	Level
Hydrogen	>99.9 %
Hydrogen Sulfide	10 ppb
CO	0.1 ppm
CO_2	5 ppm
NH_3	1 ppm
Ethylene	50 ppm

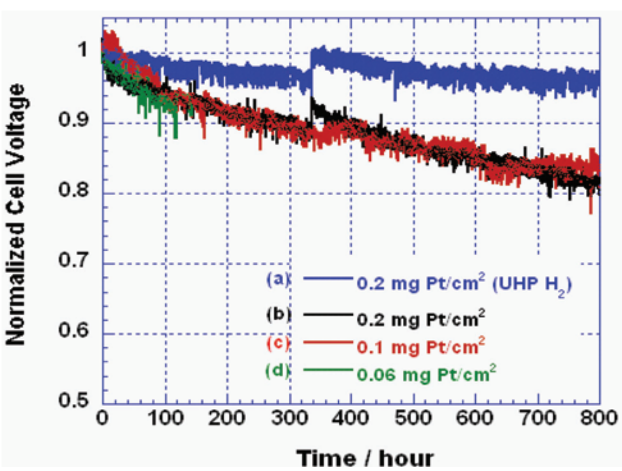

FIGURE 1. Dependence of Fuel Impurity Effect on Anode Pt-Loading (FCs operated on pure H_2 and on the fuel mixture indicated on Table 1. Top curve corresponds to a cell operated with ultra high purity hydrogen.)

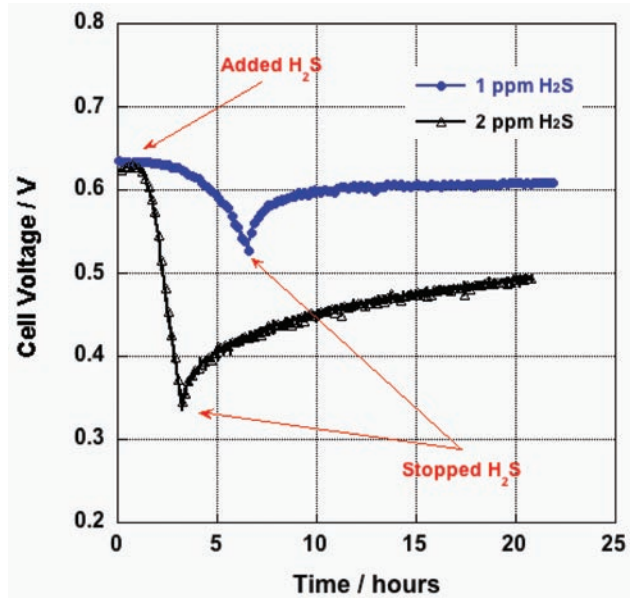

FIGURE 2. 50 cm^2 Fuel Cell Exposed to H_2S: 5 h 15 min to 1 ppm and 2 h 37 min to 2 ppm; Cell Operated at 0.80 A/cm^2 at 80°C

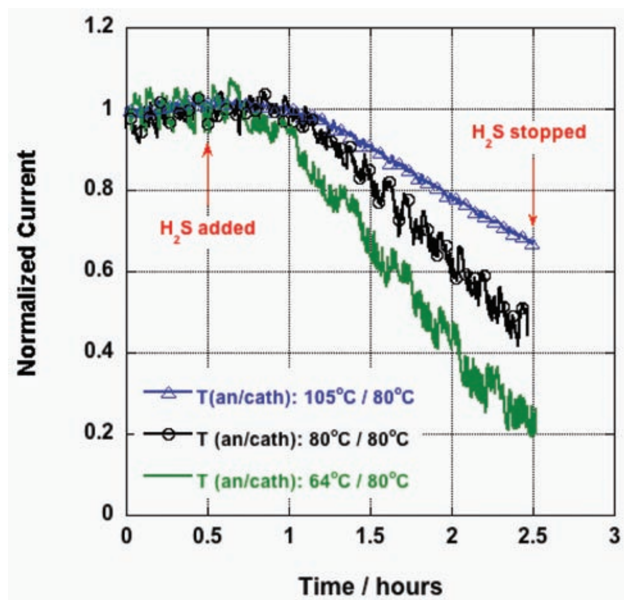

Figure 3. Effect of Anode Relative Humidity on H_2S Poisoning at 0.5 V and 80°C (Anode humidifiers temperature set at 105, 80 and 64°C.)

FY 2007 Publications/Presentations

1. F. H. Garzon, T. Rockward, I. G. Urdampilleta, E. L. Brosha and F. A. Uribe. ECS Transactions; **3**, 695 (2006).

2. T. Rockward, I. G. Urdampilleta, F. A. Uribe, F. H. Garzon. "The Effects of Multiple Contaminants on Polymer Electrolyte Fuel Cells". To be presented at the 212th ECS Meeting. Washington, D.C., Oct. 7–12, 2007.

3. F. A. Uribe, I. Urdampilleta, T. Rockward, E. L. Brosha, and F. H. Garzon. PEMFC "Poisoning with H_2S: Dependence on Operating Conditions". To be presented at the 212th ECS Meeting. Washington, D.C., Oct. 7–12, 2007.

References

1. F. H. Garzon, T. Rockward, I. G. Urdampilleta, E. L. Brosha and F. A. Uribe. ECS Transactions; **3**, 695 (2006).