Development of Novel Electrocatalyst for Proton Exchange
Membrane Fuel Cells

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ABSTRACT

Proton-exchange membrane fuel cell (PEMFC) is one of the strongest contenders as a power source for space & electric vehicle applications. Platinum catalyst is used for both fuel and air electrodes in PEMFCs. CO contamination of H_2 greatly affects electrocatalysts used at the anode of polymer electrolyte fuel cells and decrease the cell performance. Pt-Ru catalyst had been recognized to alleviate this problem by showing better tolerance to CO poisoning than only Pt catalyst. This irreversible poisoning of the anode can be happened even in concentrations as little as a few ppm, and therefore, require expensive scrubbing to reduce the contaminant concentration to acceptable level. In order to commercialize this environmentally sound source of energy/power system, development of suitable impurity tolerant catalyst is needed. This project will develop novel electrocatalysts for the PEMFCs and demonstrate the feasibility of a H_2/O_2 fuel cell base on these materials. This project, if successful, will reduce the costs due to reduce Pt catalyst loading or use non-precious metals. It will increase the PEM fuel cell performance by increasing catalyst tolerance to methanol oxidation intermediate products (CO) and fuel impurities (H_2S), which will generate substantial interest for commercialization of the PEM fuel cell technology.

TABLE OF CONTENTS

Title page	i
Disclaimer	ii
Abstract	iii
Table of Contents	iv
Executive Summary	v
Introduction	1
Experimental	2
Results and Discussion	3
Conclusions	4
References	4

EXECUTIVE SUMMARY

The power generation in the Proton Exchange Membrane Fuel Cell (PEMFC) is based on Pt as a catalyst for both the fuel and air electrodes. This catalyst is highly active but susceptible to fuel impurities such as, S and CO, which may be present in the fuel used or may be introduced during fuel processing such as, reforming. These impurities poison the anode irreversibly and decrease the performance of the PEMFCs. Our work is to develop novel electro-catalysts for PEMFCs to reduce system costs and to enhance operating life before fuel cell can become commercially competitive with conventional means of power generation in the industrialized world.

INTRODUCTION

The fundamental chemical reaction to produce water from oxygen and hydrogen is given as:

Fuel cells are electrochemical devices that convert the available chemical free energy directly into electrical energy, without going through the heat exchange process [1,2]. Earlier, it was thought that, this type of energy would be used only for some special purposes like space travel. In recent years, there have growing interest in developing fuel cell technologies for down-to-earth applications. Because of the high efficiency and almost zero emission to the environment, these fuel cells are finding applications in chemical process industries (CPI) as stand-alone or on site power generators and in motor vehicles.

The present state-of-art Proton Exchange Membrane Fuel Cell (PEMFC) technology is based on Pt as a catalyst for both the fuel and air electrodes. This catalyst is highly active but susceptible to fuel impurities such as, S and CO, which may be present in the fuel used or may be introduced during fuel processing such as, reforming. These impurities poison the anode irreversibly and decrease the performance of the PEMFCs. Work is still needed to reduce system costs and to enhance operating life before the fuel cell can become commercially competitive with conventional power systems.

In this work, we plan to develop novel electrocatalysts for PEM fuel cells and will demonstrate the feasibility of a H_2/O_2 fuel cell based on these materials. Part of the work would be focussed on developing procedure for preparing metal catalysts loaded on carbon matrix. Novel catalysts will combine with the known high activity of the Pt and other noble metals, such as Ru. Pt/Mo, Pt/Ru/Mo, Pt/W, Pt/Ru/W, Pt/WC, Pt/Ru/WC. Other possible metals may include Sn and Ir. Successful development of these electrocatalysts will lead to several advantages:

- It will eliminate the need for expensive treatment of the fuel feed stream to remove these contaminants as presently required
- It will reduce weight and result in compact fuel cell power system with improved energy efficiency
- It will lower the costs due to reduce Pt catalyst loading or use of non-precious metal catalyst and will have direct application in commercial and private sector.

The major tasks of this project may be summarized as follows.

Task 1: Synthesis of candidate electrocatalyst materials.

Task 2: Half-cell evaluation of electrocatalysts with pure Hydrogen.

Task 3: Half-cell evaluation of electrocatalysts with contaminated hydrogen.

Task 4: Electrode performance evaluation in a H_2/O_2 fuel cell.

Task 5: Final report preparation.

Based on above tasks, the project work is planned as follows.

- Set up a single cell Hydrogen/Oxygen fuel cell system
 - Obtain commercially available fuel cell components.
 - Familiarized with fuel cell operation and performance evaluation.
 - Compare performance with H₂ contaminated with CO.
 - Synthesized MEAs using commercially available catalysts and other components.
 - Compare fuel cell performance with commercial MEA V_s synthesized MEAs.
- Develop procedure for preparing metal catalyst loaded on carbon
 - Synthesize Pt and Pt/Ru catalysts and load on carbon.
 - Prepare electrode as well as MEAs using the synthesized electrodes.
 - Compare fuel cell performance with commercial MEAs V_s synthesized MEAs.
- Complete literature search to determine candidate catalysts to evaluate
 - Pt/Mo, Pt/Ru/Mo, Pt/W, Pt/Ru/W, Pt/WC, Pt/Ru/WC are likely candidates.
 - Other possible metals may include Sn and Ir.
- Evaluation of candidate catalyst materials.
 - Determine performance with pure hydrogen as well as contaminated hydrogen.

EXPERIMENTAL

Experimental set up for the H₂/O₂ fuel cell system has been developed and the flow diagram of the system is shown below:

Process flow diagram

The hydrogen generator (NITROX, UHP-40H) is used to produce H_2 gas for the system. A Multiple Dyna-Blender (model 8284), basically a combination of a flow indicator, gas mixture and flow controller (model 8270), is used to control the flow of these gases and CO for the fuel cell. A small portion of the fuel gas is bypassed to GC (Hewlett Packard, 5890 series 2) to analyze the fuel compositions. Air (compressed UN 1002) is used as a source of O_2 for this system. Two water traps are used to remove water vapor from exit gas streams.. Two Back Pressure Regulators (each are the combination of TESCO, 50 psig maximum control valve and ASHCROFT pressure gauge, 30 psig maximum) are used to maintain to constant pressure in the fuel cell system. Gases coming out from FC are then taken to the fume hood. Since we are using highly poisonous CO gas, the fuel cell system has to maintain a negative pressure. For this reason fuel cell (FC05-01SP, FC05-01SP-REF), water traps, pressure regulators, TIC and multi-meters are placed inside the fume hood. At each and every temperature and pressure and for all Membrane Electrode Assemblies (MEAs), we need to see the performance of the fuel cell. For this, two multi-meters (EXTECH data logger Multimeter,383274 and AMPROBE Model AM-9) are used, which can measure the voltage and current density, respectively.

Operating parameters and system specifications are given below:

Operating parameters & system specs

■ Fuel cell ■ $I = 0.1 - 1.1 \text{ A/cm}^2$ ■ $V = 0.1 - 1.0 \text{ volt}$ ■ $T = 60 - 75^\circ\text{C}$ ■ $P = 5 - 30 \text{ psi}$ ■ $CO = (10 - 100)\text{ppm}$ ■ $H_2 = 99.999 \%$ ■ Air = Ultra pure	■ Area of FC = 5 cm^2 ■ Membrane = Nafion[®] 117, 119 (per- fluorinated Sulfonicacid ion-exchange membrane) ■ Pt loading = (0.5 to 1) mg/cm^2 or (10 to 20) wt %

Flow rates:

H_2 : 2cc/min to 2000 cc/min
 O_2 : 1cc/min to 1000 cc/min

RESULTS AND DISCUSSIONS

This annual report covers the first year of the project ending August 31, 1999. We could not start the project at the scheduled starting date, as paper work was complete. One graduate student (S. Sharmin) was hired in early January 1999 and also one undergraduate student is assisting in the lab. The work during this reporting period has been primarily on literature search, design and set-up of fuel cell system. We have made test-runs of the fuel cell system and obtained preliminary performance curve.

During the second year of the project, we expect to obtain significant results from our catalyst development work.

In the proposed effort, high surface area, active, impurity-tolerant electrocatalyst materials will be developed and incorporated in fuel cell assemblies with commercially available polymer proton exchange membranes. The activity of electrocatalysts prepared with different compositions and preparation methods will be studied and characterized in Hydrogen half-cells as well as in H₂/O₂ fuel cells in the proposed program. The ability of these electrocatalysts to function in the presence of CO and H₂S contaminants will be demonstrated using concentrations typically found in the reformed fuel gases.

CONCLUSIONS

We have designed and built an experimental set-up to run PEMFC for testing and evaluation of its performance under various operating conditions and also with varied catalyst loading and compositions. We have completed preliminary test runs and obtained performance curve for base-line PEMFC case. We plan to extend this work to test newly formulated electrocatalysts and performance test would enable us to narrow down candidate catalysts for further evaluation. We expect to complete this work in next twelve months.

REFERENCES

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2. Appleby, A.J., and Foulkes, F.R., *Fuel Cell Handbook*, Van Nostrand Reinhold, New York, 1989.