

Integrated Fuel Processing for Low-Temperature & High-Temperature Fuel Cells

Goal

To develop effective adsorbent and catalytic materials as well as processing methods for integrated fuel-cell fuel processor including adsorption desulfurization, catalytic oxidative reforming and hydrogen production on-site or on-board.

Team

A partial list of organizations that work with The Energy Institute in fuel-cell fuel processing research and development include: U.S. Department of Energy (DOE), National Energy Technology Laboratory (NETL), and U.S. Department of Defense (DOD), Engelhard Corporation, Conoco Phillips Corporation, Air Products and Chemicals Inc., and Altex Technologies Inc.

Program Discussion

The Energy Institute is currently involved in several projects that involve either gaseous/liquid hydrocarbon fuel or alcohol fuel in one or more of the following fuel-cell fuel processing steps: desulfurization of organic sulfur, pre-reforming of higher hydrocarbons, reforming for synthesis gas generation, carbon formation during hydrocarbon reforming, water gas shift for H₂ production, selective CO oxidation for deep CO removal. The target fuel cells for our fuel processor research includes low-temperature fuel cell based on polymer electrolyte, and high-temperature fuel cells based on solid-oxide electrolyte. The target processors include both micro-fuel cell fuel processors for man-portable applications and those for residential and automotive applications.



Reactor for Liquid Fuel Reforming for Fuel Cells

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Background

A fuel cell is an electrochemical device in which the chemical energy stored in a fuel is converted directly into electricity. Fuel cells operate without combusting fuel and with few moving parts, and thus they are very attractive from both energy and environmental standpoints. Proton exchange membrane (PEMFC) fuel cells and solid oxide fuel cells (SOFC) are considered to be promising fuel cells for mobile and stationary applications.

The candidate fuels for fuel cells include natural gas, propane gas, gasoline, jet fuel, diesel fuel, methanol, ethanol, biomass, coal, and pure hydrogen. Since pure hydrogen, the ideal fuel for fuel cell, is not readily available due to lack of distribution infrastructure and lack of storage methods, the on-site or on-board production of hydrogen is considered to be the most promising way for using stationary (residential, etc.) and mobile (transportation, etc.) fuel cell systems in the near- and mid-term. Consequently, it is increasingly recognized that the fuel processing subsystem can have a major impact on overall fuel cell system costs.

A stumbling block for hydrocarbon fuel processor development is that there is not yet an effective means of removing sulfur for fuel cell applications. Hydrocarbon fuels derived from petroleum contain sulfur in high concentrations, up to 350 ppm in gasoline and up to 500 ppm in diesel and up to 3000 ppm in jet fuels. Even with the EPA 2006-2010 regulations, sulfur contents in gasoline (30 ppm) and diesel (15 ppm) are still too high for fuel cell applications. Methanol, synthesized from fossil fuels via synthesis gas generation and catalytic synthesis, is sulfur-free but it has much lower energy density than liquid hydrocarbon fuels.

Results

A new method called selective adsorption for removing sulfur (SARS) has been developed for on-site organic sulfur removal in stationary fuel cells and for on-board desulfurization for automotive fuel cell system. SARS works for making ultra-clean fuels using solid adsorbent that selectively interacts with sulfur compounds in the presence of aromatic compounds at room temperature (e.g., 30 °C), and does not use hydrogen or other reactive gases. SARS has been demonstrated in laboratory scale for making ultra-low-sulfur (<1 ppm) gasoline and diesel fuels as well as JP-8 jet fuels.

Both steam reforming and catalytic oxidative steam reforming are being explored in our laboratory for efficient synthesis gas and hydrogen production. Effective method for studying carbon formation during reforming of hydrocarbon fuels has

been developed that involve a dynamic technique called tapered element oscillating microscope (TEOM) for characterization of carbon formation during real reforming reactions, and a reactive technique called SR-TPO-IR that combines reforming followed by TPO with IR analyzer for examining reactive features of carbon formed during hydrocarbon reforming reactions.

Effective method and process conditions are being developed for inorganic sulfur (H_2S) removal from steam-containing gas mixtures (reformate) after hydrocarbon



Reactor for Desulfurization before/after Reforming for Fuel Cells

reforming, which can be used as a polishing bed both for low-temperature and high-temperature fuel cell systems.

Integrated catalytic processing methods are being developed for CO conversion in low-temperature water gas shift reaction and for selective CO oxidation for low-temperature fuel cells based on polymer electrolyte. This applies to both alcohol (methanol) fuel reformer and hydrocarbon reformer for low-temperature fuel cells.

Key Publications

C. Song (1). Catalytic Fuel Processing for Low- and High-Temperature Fuel Cell Applications. Challenges and Opportunities. Proceedings of Topical Conference on Fuel Cell Technology. AIChE 2002 Spring National Meeting, New Orleans, March 11-14, 2002, pp. 125-135.

X. Ma, M. Sprague, L. Sun, and C. Song. Deep Desulfurization of Liquid Hydrocarbons by Selective Adsorption for Fuel Cell Applications. Am. Chem. Soc. Div. Petrol. Chem. Prepr., 2002, 47 (1), 48-49.

S.T. Srimat, W. Pan, C. Song, and J. N. Armor. Dynamic Characterization of Carbon Formation during CO_2 Reforming and Steam Reforming of CH_4 Using Oscillating Microbalance. Am. Chem. Soc. Div. Fuel Chem. Prepr., 2001, 46 (1), 92-93.

I. Novochinskii, X. Ma, C. Song (2), J. Lambert, L. Shore, and R. Farrauto. A ZnO-Based Sulfur Trap for H_2S Removal from Reformate of Hydrocarbons for Fuel Cell Applications. Proceedings of Topical Conference on Fuel Cell Technology. AIChE 2002 Spring National Meeting, New Orleans, March 11-14, 2002, pp. 98-105.

J.-P. Shen and C. Song (2). Catalyst for Low-Temperature Reforming of Methanol for Fuel Cell Applications. Influence of Metal Precursor on Performance of Cu/ZnO- Al_2O_3 Catalysts. Am. Chem. Soc. Div. Fuel Chem. Prepr., 2001, 46 (2), 667-668.