Project status: Ongoing

P R O J E C T   F A C T   S H E E T

Solid Oxide Fuel Cells Operating on Heavy Hydrocarbon Fuels

Goal

Most of fuel cells operate on hydrogen or light hydrocarbon fuels such as methane or methanol. This project is aimed to develop a SOFC that operates on less processed heavy hydrocarbon fuels, such as, jet fuels as well as regenerable bio-fuels.

Team

Serguei Lvov, Program Coordinator
ZhuangFei Zhou, Research Associate
Mark Fedkin, Research Associate

This research project is sponsored by the Energy Institute of Penn State University.

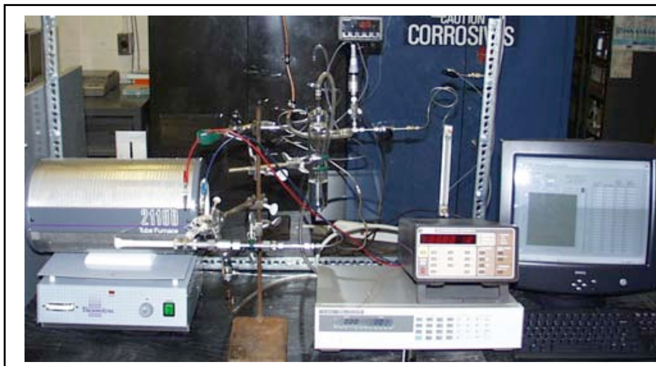
The Energy Institute • www.energy.psu.edu
College of Earth & Mineral Sciences • Penn State University

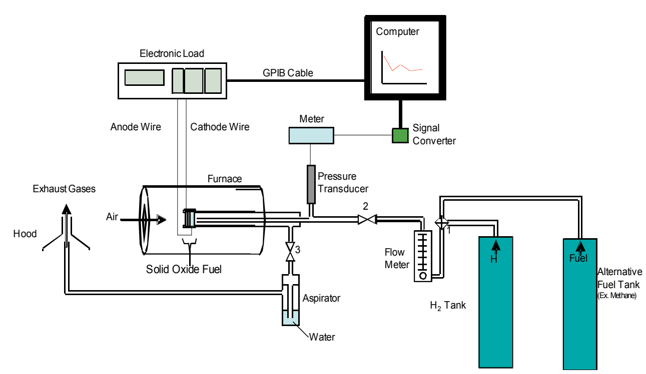
Background

Among the major types of fuel cells, solid oxide fuel cells (SOFC) differ from others. In a SOFC, O_2 is reduced to O^{2-} anions at the cathode before the anions migrate to the anode through a solid electrolyte. The oxidation of the O^{2-} anions at the anode produces electrons, which forms an electricity generating circuit with the cathode. SOFCs, however, need to operate at high temperatures (>500°C) when solid electrolytes become ionic conductors. The high temperature may allow direct oxidation of hydrocarbon fuels. Some success in direct oxidation of light hydrocarbons has been reported with methane and natural gas. Until the recent development of the Cu-ceria anode SOFC, direct oxidation of heavier hydrocarbons had not been possible primarily because of coke formation.

Project Discussion

It has been demonstrated that the ability of the Cu-ceria SOFC in the direct oxidation of hydrocarbon fuels without reforming is due to the stability of the anode towards coke formation. This ability to avoid coke formation is a result of the synergetic roles of Cu and ceria employed in the composite anode present in the SOFC. The SOFC has since been shown to generate electric power using a number of fuels other than H_2. These include methane, butane, ethane, butene, hexane, *n*-decane, toluene, synthetic diesel and gasoline, although the liquid fuels need N_2 for dilution. Along with the success in direct oxidation of some heavy hydrocarbon fuels, the SOFC was also found to tolerate a reasonable amount of sulfur in a liquid fuel. It generated stable electric power on *n*-decane that contained 100 ppm sulfur, despite the fact that 5000 ppm sulfur rapidly poisoned the anode. It is the aim of this study to examine if a number of less processed heavy hydrocarbon fuels can be used as fuel for SOFC. In addition to ceria and ceria-Cu anodes, a precious metal catalyst is also added to ceria anode. Their performance on the direct oxidation of hydrocarbon fuels is discussed herein.





Results

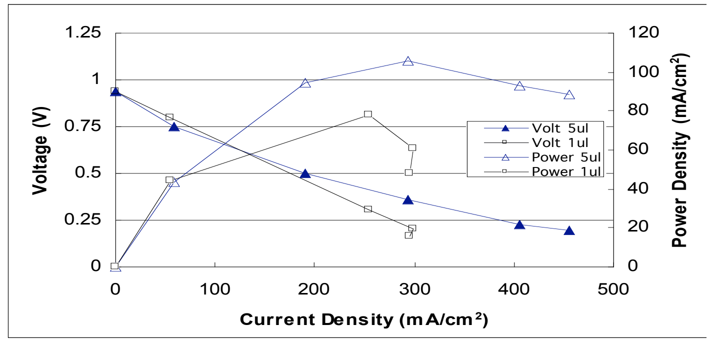
The performance of our SOFCs are demonstrated by assessing both voltage-current density relationships and voltage/current density vs time for long term stability.

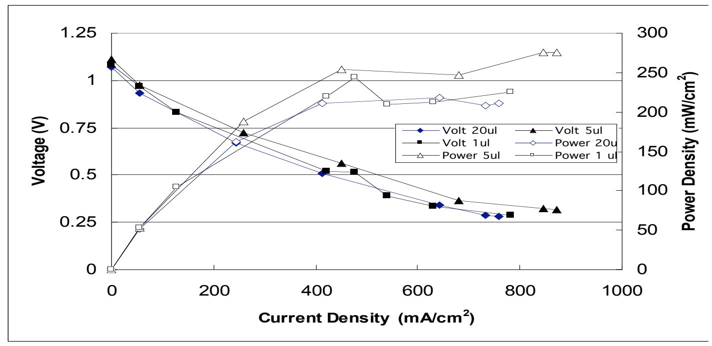
The top figure on the right exhibits the voltage-current density and power density-current density performance curves for a SOFC with ceria-Cu anode at 973 K at two different fuel supply rates - 1 and 5 μl/min. The fuel is a waste vegetable fuel. Open circuit voltages are about 0.9V which is slightly less than the Nernst potential. The maximum power density seems varied with the fuel supply rate with the higher fuel supply rate producing higher power density. A maximum power density of approximately 100 mW/cm2 is achieved.

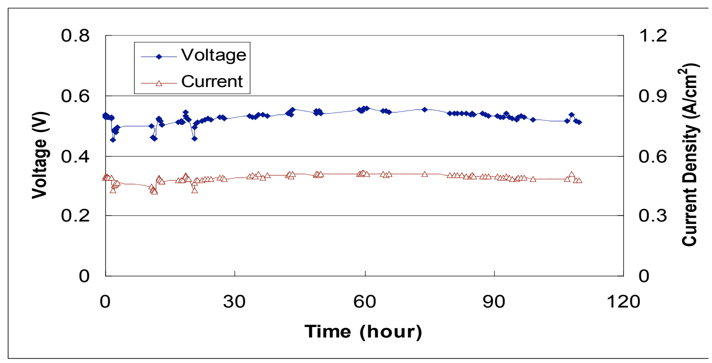
The middle figure on the right presents a set of typical voltage-current density and power density-current density performance curves for a SOFC with ceria-Rh anode at 973 K, which is also fueled with the same waste vegetable fuel at three different supply rates, 1, 5, 20 μl/min. Open circuit voltages are about 1.1 V that are close to the Nernst potential. A power density of approximately 250 mW/cm2 is obtained even at a fuel supply rate of 1 μl/min. The addition of precious metal is, hence, shown to significantly improve the performance of the SOFC.

The bottom figure on the right shows a typical long term performance of a SOFC with Ce-Rh anode at 973 K. The stable voltage and current density over more than one hundred hours demonstrate the stability of the fuel cell.

In addition, we have demonstrated that other hydrocarbon fuels including various jet fuels and even Pennsylvania crude oil can be used to fuel the SOFC (see references below). Our current research focuses include improvement of the long term stability and catalysis of the Ce-based anode.







Key Contacts

S. Lvov, lvov@psu.edu, (814) 863-8377

Z. Zhou, zuz2@psu.edu, (814) 865-7176

M. Fedkin, mvf3@psu.edu, (814) 865-3280

Key Publications

Z.F. Zhou, R. Kumar, S.T. Thakur, L.R. Rudnick, H. Schobert, and S.N. Lvov, "Direct Oxidation of Waste Vegetable Oil in Solid Oxide Fuel Cells" 3rd Inter Conf. on Fuel Cell Science, Engineering and Technology, May 2005, Michigan.

Z.F. Zhou, C. Gallo, M.B. Pague, H. Schobert, and S.N. Lvov, "Direct Oxidation of Pennsylvania Crude Oil and Jet Fuels in Solid Oxide Fuel Cell" Journal of Power Sources, **133** (2004) 181-187.