Microchemical Systems for Fuel Processing and Conversion to Electrical Power

Personnel

L. Arana, C. Baertch, J. Chou, J. Cui, C. Delattre, J. Hertz, A. Ie, C. Lee, A. Mitsos, O. Nielsen, I. Palou-Rivera, T. Stefanik, K. Turner, S. W., K. Jensen, P. I. Barton, S. Spearing, M. A. Schmidt, H. L. Tuller, and J. Y. Ying

Sponsorship

ARO MURI

This program aims to develop a fundamental understanding of the different physical phenomena underlying fuel processing at millimeter to micron scale as well as to establish the engineering principles needed to realize portable electrical power generation from hydrocarbon fuels.

Portable, high density power sources have been identified as an enabling technology. A continued reliance on batteries, combined with their relatively low projected energy densities, create serious logistical mission constraints. Taking advantage of the high energy density of chemical fuels to generate power becomes an attractive technological alternative to batteries. However, development of fuel processors capable of chemical/electrical conversion with a net power output on a portable scale represents a significant technological challenge.

Microreactors as miniature fuel processors represent an emerging technology that could significantly impact our ability to produce high density power sources in the future. The program aims to develop a fundamental understanding of the many different physical phenomena underlying fuel processing at millimeter to micron scale as well as to establish the engineering principles needed to realize portable electrical power generation from hydrocarbon fuels based upon advances in microfabrication, fuel cells, catalysis, materials characterization, and systems engineering. Competing approaches to fuel conversions are addressed with particular emphasis on two basic strategies:

- Conversion of hydrocarbons to hydrogen for use in a hydrogen fuel cell by partial oxidation, reforming, and product separation steps.
- Direct conversion of hydrocarbon fuels in a microfabricated solid oxide fuel (SOFC) cell system integrated with microfluidic controls.

In order to address the many different aspects of microfabricated fuel processing systems, we have a multidisciplinary research team that combines the necessary expertise, specifically in the areas of thermomechanical properties of materials, materials synthesis, microfabrication, chemical reaction engineering, heat transfer, catalysis, simulations, and systems engineering. This multidisciplinary research program has set the following goals for the proposed effort:

- Development of design and microfabrication strategies for microchemical systems capable of operating at elevated temperatures and being rapidly cycled between low and high temperatures. This will entail the development of novel fabrication strategies involving high temperature materials such as oxides not currently used in standard, mainly silicon-based, microfabrication methods.
- Synthesis and characterization of novel catalytic materials for low temperature partial oxidation and reforming as well as for novel SOFC electrodes. In particular, tailored heterogeneous catalytic surfaces for microchemical systems will be generated by forming nanostructured features on surfaces of micron-scale flow channels.
- Fundamental understanding and engineering approaches to integration of materials with different thermophysical properties into systems undergoing large spatial and temporal temperature variations.
- Fundamental understanding of transport and reaction processes in microchemical systems. Development of engineering design principles and simulation tools for microreactor systems.
- Systems engineering concepts and tools for understanding and predicting the performance of integrated microchemical systems at steady state and during transients, i.e., dynamic behavior.

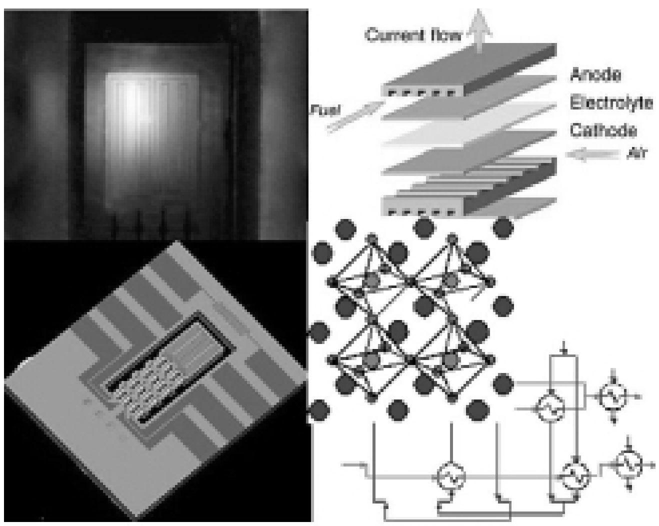

Fig. 49: Different elements of the fuel processing program; fuel processor, microcombustor, solid oxide fuel cell schematic, crystal structure of catalysts, energy integration diagram.