6. Micro fuel cells and micro reactors for fuel processing

Micro-Solid Oxide Fuel Cells as power supply for small portable electronic equipment

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This paper reports on the development of a micro-Solid Oxide Fuel Cell (SOFC) system for powering small, portable electronic devices, such as laptop, personal digital assistant (PDA), medical and industrial accessories. It is predicted that micro-SOFC systems have a 2-4 time higher energy density than Li-ion batteries [1]. However, literature reports mainly focus on the fabrication and characterization of thin films and membranes for micro-SOFC systems [2-12]; the entire system approach is not yet studied in detail.

We will therefore discuss in this paper the entire approach from the fabrication of thin films and membranes up to the complete system, including fuel processing, thermal management and integration. The general system design integrating all sub-units in one system is schematically shown in Fig.1. The following topics will be discussed in detail:

1. *Micro-SOFC membrane fabrication and characterization:* Different processing approaches and different designs for micro-SOFC membranes will be discussed. These include typical thin film micro-electro mechanical systems (MEMS) processing techniques (Fig. 2) [13], such as thin film deposition and microfabrication, as well as wet ceramic processing of ultra-thin ceramic tapes (< 10 μm thick) [14]. We will present membrane performances of differently processed micro-SOFC membranes and will discuss advantages and disadvantages of the single approaches and designs.
2. *Fabrication and characterization of microfabricated gas processing unit:* Based on our previous studies on packed bed reformer of a new foam-like catalyst material [14], we fabricated for the first time a reformer with MEMS technologies and filled it with a porous ceramic foam based on nanoparticle catalyst material (Fig. 3). This microfabricated reformer qualifies for direct stacking with SOFC membranes and is tested with respect to butane conversion and hydrogen reforming as a function of temperature and fuel composition at temperatures between 300 and 600°C.
3. *Thermal system management:* We propose a thermal system management that allows for a temperature gradient of about 500°C between hot SOFC membrane (550°C) and outside system (35°C). This concept is based on a gas flow system with heat exchange for inflow preheating and a separate exhaust gas cooling (Fig. 4). The thermal system of this micro-system will be compared to traditional large scale SOFC systems.
4. *Integration and packaging:* Typical MEMS techniques are evaluated for integration and packaging in this complex micro-SOFC system approach including high temperatures, oxidizing and reducing gases and gas tightness requirements. A packaging concept will be proposed and will be compared to alternative low temperature co-fired ceramic (LTCC) packaging.

Considering all sub-units, we can prove the operating and fabrication feasibility of a micro-SOFC system.

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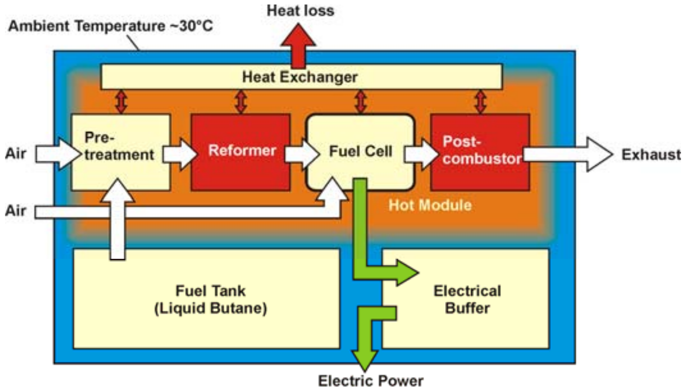

Figure 1. Sketch of an integrated micro-Solid Oxide Fuel Cell system design.

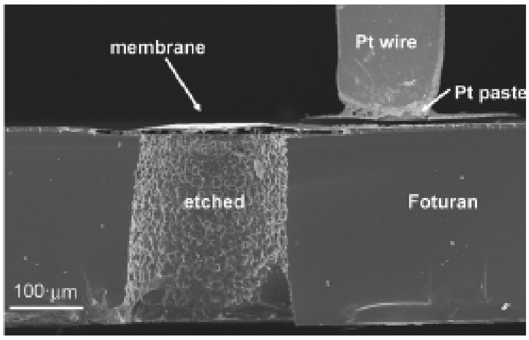

Figure 2. Scanning Electron Microscopy cross section image of a three-layer micro-SOFC membrane on a Foturan substrate.

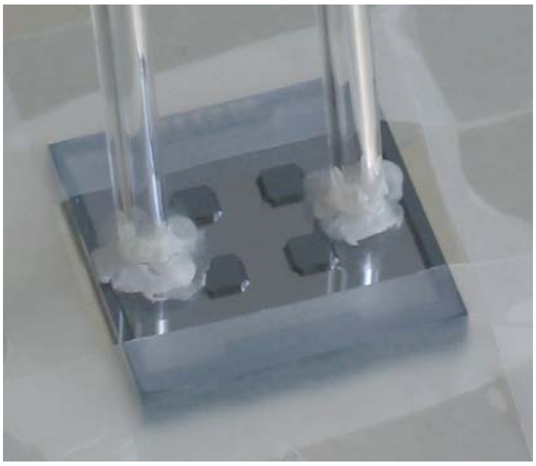

Figure 3. Microfabricated reformer including testing tubes.

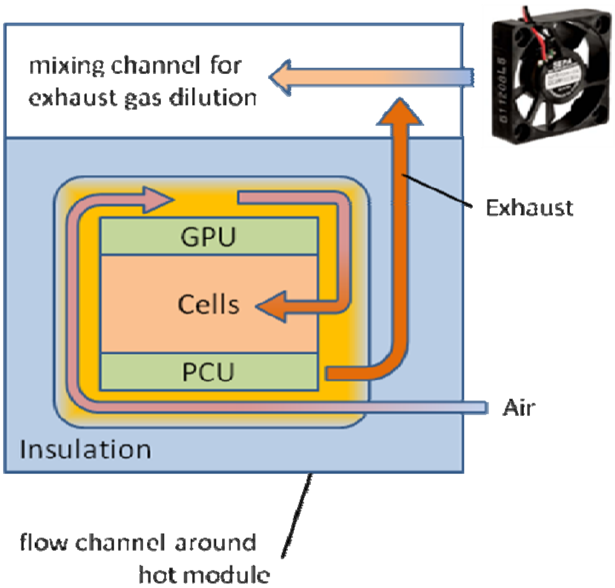

Figure 4. Thermal management concept without exhaust gas heat exchanger.