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

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Introduction

Micro-Solid Oxide Fuel Cell (SOFC) systems are anticipated 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 mainly focuses 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.

Results and Discussion

The general system design integrating all sub-units in one system is schematically shown in Fig.1. The main unit is the fuel cell with the reformer and the post-combustor which build altogether the so-called hot-module. The temperature of the hot module is fixed currently at 550°C, but the lower the temperature, the better for a portable device. Main reasons for this temperature range of 550°C are due to the electrochemical activity of the fuel cell itself (rather high temperature is required for good ionic conductivity) as well as the catalytic activity of the reformer and the post-combustor referred in the gas processing unit.

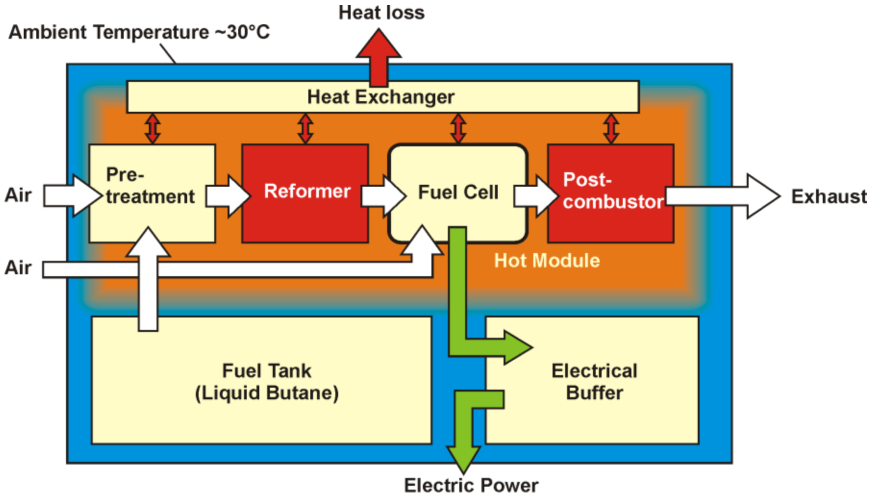

Figure 1. Sketch of an integrated micro-Solid Oxide Fuel Cell system design.

The investigations are split into four main subtasks: fuel cell development, gas processing development, thermal system management, and packaging and integration:

1. Micro-SOFC membrane fabrication and characterization: Different processing approaches and different designs for micro-SOFC membranes are currently studied. These include typical thin film micro-electro mechanical systems (MEMS) processing techniques [13], such as thin film deposition and microfabrication, but also ceramic processing of ultra-thin ceramic tapes (< 10 µm thick) [14]. Fig. 2 shows a scanning electron microscopy cross section through a free-standing, multi-layer (anode-electrolyte-cathode) membrane integrated onto a Foturan substrate. Performances of up to 238 mW/cm^2 at 550°C were measured with such kind of micro-SOFC membrane. Fig. 3 shows a self-sustaining, 3 µm thick and 16 cm^2 yttria stabilized zirconia foil that was prepared by wet ceramic processing. Usually, wet ceramic processed tapes have thicknesses of several hundred micrometer. Electrical properties of these tapes are comparable to bulk and thin film material; hence, these tapes are very promising for micro-SOFC devices.

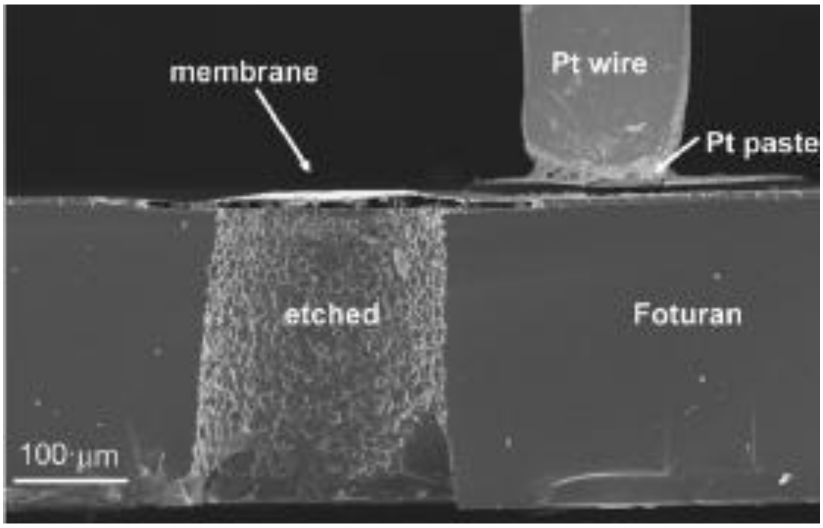

Figure 2. Scanning Electron Microscopy cross section image of a three-layer micro-SOFC membrane on a Foturan substrate.

Figure 3. Ultra-thin YSZ ceramic foil prepared by wet ceramic processing.

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. 4). 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.

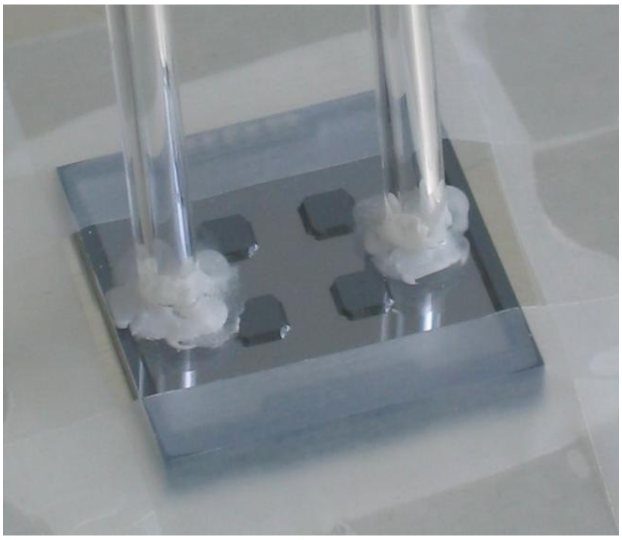

Figure 4. Microfabricated reformer including testing tubes.

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. 5). The thermal system of this micro-system is compared to traditional large scale SOFC systems.

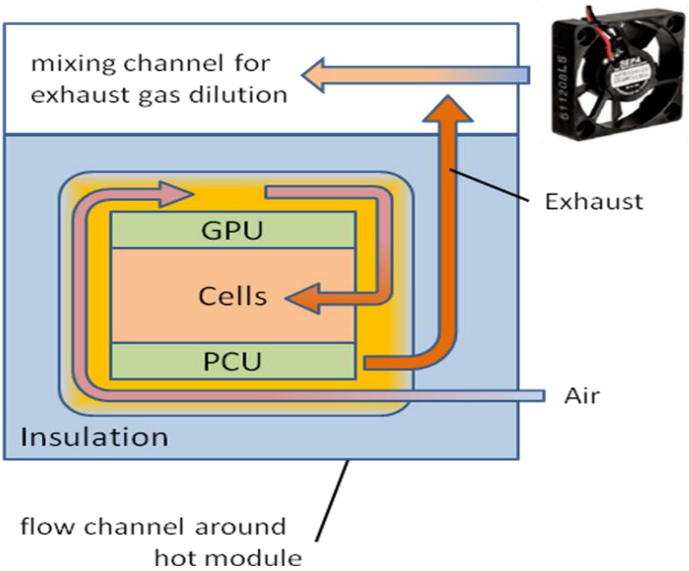

Figure 5. Thermal management concept without exhaust gas heat exchanger.

4. Integration and packaging: Integration and packaging is a very challenging task for the development of a micro-SOFC system due to the high operating temperatures of up to 550°C, oxidizing and reducing gases, multiple-wafer design for one single subunit of fuel cell and gas processing unit, as well as the requirement of gas-tightness for separating anodic and cathodic gas rooms. This means that no standard bonding technologies can be used and that several bonding technologies have to be combined for hot module fabrication. After evaluating a feasible processing flow for one subunit in the hot module in detail, we found that processing is in principle feasible; however, more detailed research in alternative bonding techniques is required.

Conclusion

Considering all sub-units, we can prove the operating and fabrication feasibility of a micro-SOFC system. First sub-units were fabricated and work in principle.

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