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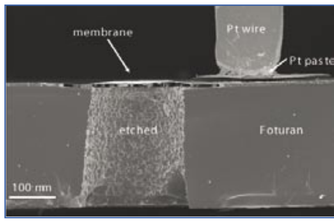
Competence Center Energy and Mobility

ONEBAT

Battery Replacement Using Miniaturized Solid Oxide Fuel Cell

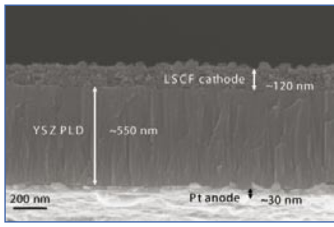
Scope of project

The main aim of the ONEBAT consortium is the development of a micro-Solid Oxide Fuel Cell (SOFC) system. This is a very complex task and includes solving many different problems which can only be tackled within a multidisciplinary consortium consisting of material scientists, physicists, chemists, mechanical and chemical engineers. The main tasks are the development of a microfabricated thin film SOFC, a small-scale gas processing unit, a feasible thermal system and the integration of all subsystems into one single system.



Above: SEM cross section view of a μ-SOFC on a Foturan® substrate.

Below: Blow-up view of the three layer membrane.



Goals and activities

Fuel cell development

The main goal in the last year of the project was to fabricate SOFC membranes that withstand SOFC operating conditions and which lead to considerable power output.

Main scientific results

It was possible to fabricate free-standing, multilayer membranes on FOTURAN substrates. The multi-layers are crack-free, consist of dense electrolyte and porous electrodes, and are stable up to 600°C. Each layer, i.e. cathode, electrolyte, and anode, was optimized and characterized individually.

Performance of such a cell: almost theoretical OCV of 1.06 V and a power output of 150 mW/cm^2 at 550°C were obtained. This is an excellent result; in particular with respect to the fact that only one group worldwide was able so far to show electrochemical performance of a micro-SOFC.

Since the performance strongly depends on the materials and microstructure of the different thin films which can be varied by deposition methods, higher performances are expected in the near future.

In parallel to the approach with Foturan substrates, SOFC membranes with nickel grid supporting anode were fabricated using silicon wafers as substrate material. Free-standing YSZ membranes with a thickness of 500 nm and a huge diameter of up to 5 mm were fabricated and are mechanically stable up to 600°C with the help of the nickel grid.

In summary, it was shown that free-standing three layer membranes can be fabricated both on Foturan as well as on Si. Currently, better electrochemical performance is obtained from the Foturan based cells, while larger membrane dimensions can be realized with the Si design.

Gas processing unit

The aim of this workpackage was the development and investigation of butane-to-syngas processing and post-combustion of the SOFC exhaust in micro-reactors for incorporation into an entire micro fuel cell system.

The main goal was to achieve high catalytic performance for these two components at a relatively low operating temperature of 550°C.

Main scientific results

To better meet the geometric requirements of the ONEBAT project, a novel disk-shaped reactor design was developed and tested. The feasibility of Rh/ceria/zirconia nanoparticles as a catalyst for efficient butane-to-syngas processing

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Project Partners
ETHZ (NMW, LTNT)
EPFL
ZHW
NTB

was investigated at moderate temperatures. It was shown that Rh/ceria/zirconia had an excellent long-term stability and achieved very high C_4H_{10} conversion and syngas selectivity, considering the relatively low operating temperature. The introduced disk-shaped packed bed reactor showed significant advantages in catalytic behavior, at a 6.5 times lower pressure drop compared to an equivalent tubular packed bed reactor.

A butane conversion of 90 %, hydrogen selectivity of 81 %, and carbon monoxide selectivity of 66 % could be achieved for a extremely small reactor volume of 40 mm^3 (containing 10 mg catalytic Rh/ceria/zirconia nanoparticles) for a total inlet flow rate of 30 sccm, which corresponded to 0.34 g/h butane.

Thus the required milestones, especially the necessary reactor volume, were fulfilled very clearly. Furthermore, the reactor showed very stable catalytic performance (less than 1 % deactivation) for more than 30 h.

For the post-combustor, catalytic Pt/Pd/ceria/zirconia nanoparticles proved to be a very appropriate catalyst, leading to complete conversion of all toxic (e.g. carbon monoxide) and flammable (e.g. butane and hydrogen) species in the exhaust gas of a SOFC operated at typical conditions. Using this catalyst, the necessary post-combustor temperature could be lowered significantly, reaching operating temperatures below 500° C.

Thermal system management

Main focus within this workpackage is the question whether it is possible to realize the large temperature gradient of about 500° C between hot module inside the system and the exterior.

Main scientific results

Three-D and 2D thermo-fluidic finite element models were setup in order to simulate the temperature distribution in the entire hot module as well as in the fuel cell stack only. It was found that a temperature drop of about 500° C from inside to outside is feasible. The temperature distribution within the stack is larger than expected and has to be improved.

System development

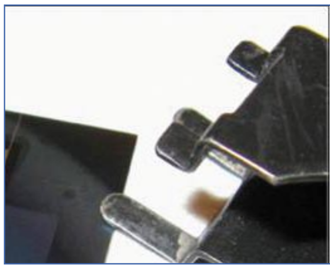
Detailed design studies on the system level were carried out. These included among others the arrangement of the fuel cell stack, the gas processing unit, the gas distribution, and heat exchanger. The arrangement has strong influence on the temperature distribution, the gas flows, the number of wafer levels to be stacked and bonded as well as pressure drop.

Project management and industrial liaison

Collaboration with Hilti (shaking tests of SOFC membranes and feasibility study) and Mikroglas (know-how exchange on FOTURAN processing and characterization).

Publications

- D. Beckel, A. Bieberle-Hütter, A. Harvey, A. Infortuna, U.P. Muecke, M. Prestat, J.L.M. Rupp, L.J. Gauckler, J. Power Sources 173 (2007) 325–345.
- D. Beckel, B. Danick, A. Bieberle-Hütter, J. Courbat, N.F. De Rooij, L.J. Gauckler, J. Power Sources, 166 (2007) 143–148.
- D. Beckel, U.P. Muecke, T. Gyger, G. Florey, A. Infortuna, L.J. Gauckler, Solid State Ionics 178 (2007) 407–415.
- J.L.M. Rupp, C. Solenthaler, P. Gasser, U.P. Muecke and L.J. Gauckler, Acta Materialia 2007, 55 (10), 3505.
- J.L.M. Rupp, T. Drobek, A. Rossi and L.J. Gauckler, Chemistry of Materials 2007, 19 (5), 1134.
- J.L.M. Rupp, A. Infortuna and L.J. Gauckler, J. of American Ceramic Society 2007, 90 (6), 1792.
- J.-W. Son, H. Kim, H.-R. Kim, J.-H. Lee, H.-W. Lee, A. Bieberle-Hütter, J.L.M. Rupp, U.P. Muecke, D. Beckel, L.J. Gauckler, J. Korean Ceramic Society 44 (10) (2007) 589–96.
- T. Salkus, A. Kezionis, A. Dindune, Z. Kanepe, J. Ronis, J. Miskinis, V. Kazlauskiene, L.J. Gauckler, U.P. Mucke, A.F. Orliukas, J. Phys: Cond. Matter 19 (2007) 106204.
- A. Bieberle-Hütter, D. Beckel, A. Infortuna, U. P. Muecke, J. L.M. Rupp, L. J. Gauckler, S. Rey-Mermet, P. Muralt, N. R. Bieri, N. Hotz, M. J. Stutz, D. Poulikakos, P. Heeb, P. Müller, A. Bernard, R. Gmür, T. Hocker, J. Power Sources, 2007 in press.
- D. Beckel, A. Dubach, A.N. Grundy, A. Infortuna, L.J. Gauckler, J. Europ. Ceramic Soc. (2007) accepted for publication.
- M.J. Stutz, D. Poulikakos, «Optimum washcoat thickness of a monolith reactor for syngas production by partial oxidation of methane», Chem. Eng. Sci. (2007) accepted for publication.
- N.B. Raberger, M.J. Stutz, N. Hotz, and D. Poulikakos, «Simulation of the Post-Combustor for the Treatment of Toxic and Flammable Exhaust Gases of a Micro SOFC», J. Fuel Cell Sci. Tech. (2007), accepted for publication.



View of a microfabricated SOFC chip with a 5 mm diameter free-standing YSZ membrane.

Info web page
http://www.nonmet.mat.ethz.ch/research/onebat

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