SOFC stack as used for teaching purposes.

CORE-SOFC increases stack life

C O R E - S O F C

Objectives

The Solid Oxide Fuel Cell (SOFC) consists of a dense solid electrolyte and two porous electrodes in contact with an interconnect on either side. The electrochemical electrode reactions occur near the interfaces with the electrolyte, i.e. oxygen reduction in the cathode and hydrogen oxidation in the anode at temperatures of 1000°C or below. SOFCs can be realised in planar or tubular designs. Recent developments tend towards cost-effective planar concepts that have thin electrolytes allowing lower temperature operation and cheap and commercially available metallic interconnects. In particular, this project aims to improve the component reliability (giving the acronym CORE) of planar SOFC systems using ferritic steels as interconnects for cost competitive reasons, and in general, to demonstrate a loss in performance of less than 0.75% per 1000 hours of operation during long-lasting experiments, including thermal cycling under realistic operating conditions.

Problems addressed

It is widely recognised that the degradation rate of an SOFC should be significantly below 1% voltage loss per 1000 h of operation time as when stationary applications like small power plants or remote power supply stations are envisaged. The proposed project focuses exclusively on planar SOFCs with 10-30 μm thin film electrolytes and with metallic interconnects and stacking parts, for which, however, the low degradation rate still needs to be demonstrated. The main technological drawback of such very efficient fuel cell systems is a degradation rate in the range of 2-20% during stack tests. It has been realised that the long-term behaviour of the interconnect material plays a crucial role in SOFC stack operation. Therefore the corrosion behaviour and the interaction of the metallic interconnect materials with adjacent ceramic components are of special concern in the project. However, the materials selection is only the first step towards the verification of durable performance of an SOFC stack. Therefore the electrochemical and mechanical stability of the SOFCs used in this project are investigated. The combination of the fuel cells with the interconnect materials are tested in contact resistance measurements and electrochemical endurance tests. It is an additional aim of the project to minimise the electrical resistance at the metal/ceramic interfaces reaching a contact resistance of less than 50 mW/cm^2. Furthermore, the mechanical assessment of SOFCs helps to pinpoint critical design issues and lead to stacks that can withstand thermal cycles.

Project structure

The three leading research centres of SOFC technology in Europe – Forschungszentrum Jülich, ECN Petten and Risø National Laboratory – are the main project partners. Due to the advanced fabrication facilities at ECN in a pilot plant scale, the project benefits from fast and "uniform" fuel cell production. A further contribution of ECN is test rigs for long-term reliability tests and contact resistance measurements. Risø with their long experience in fuel cell development are well equipped with electrochemical testing facilities and with metallographic characterisation methods, which are indispensable for the oxidation studies in this project. Jülich delivers the interconnects and contact layers and has sophisticated mechanical testing rigs available, with which the thermal cycling of cells and stacks and also *in-situ* observations are possible. Jülich has made significant progress during the recent years in construction and assembling of fuel cell stacks and provides the test facility for stack tests to prove the achieved long-term stability under oper-ating conditions.

Haldor Topsøe and Rolls-Royce, both involved in fuel cell development, supply ceramic powders and stacks to the project, respectively. Whereas Haldor Topsøe's perovskite powders are used for the fabrication of cathodes and cathode contacts, Rolls-Royce is concerned with improving the performance and lifetime of their stacks.

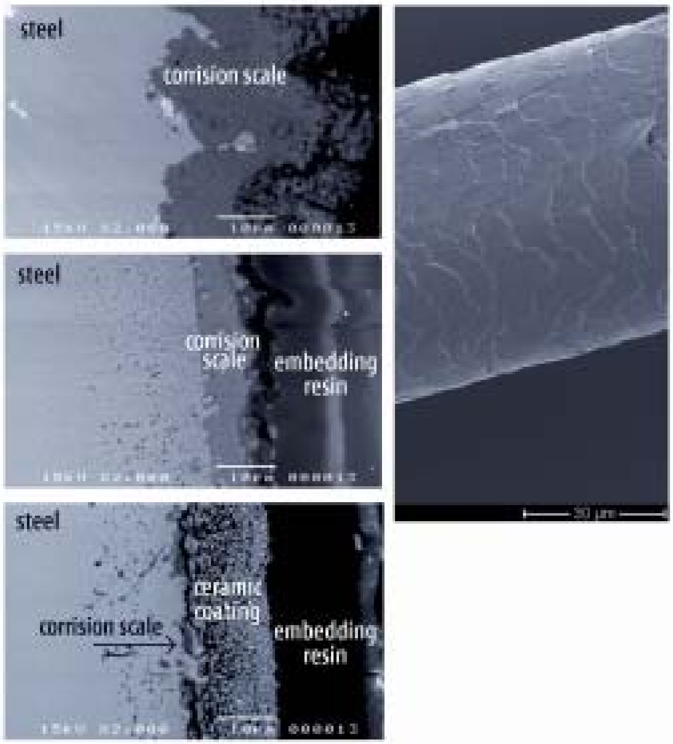

Figure 1: Left-hand side from top to bottom: Two steels and one steel sample coated with a porous ceramic layer after exposure in air at 850°C for 1000 h. Even the worst corrosion scale (top image) having a thickness of 10 µm is about six times thinner than a human hair shown on the right side for comparison in the same magnification.

Expected impact and exploitation

Reduction of degradation rates in SOFC stacks has a substantial impact on the commercial viability of SOFC systems. As an example of small SOFC systems for residential applications, it is expected that the fuel cell stack will comprise approximately 30% of the total system cost. A reasonable expected system cost for a 1 kW system is approximately 1000 €. If a 2-year (17,500 hours) stack life is considered, then the present value of stack replacements, assuming a 10% rate of return, over a 10-year period will be about 270 €. By comparison, a 50,000 hour stack life yields a present value of stack replacements of approximately 130 €. The 140 € difference, when compared to a 1000 € system cost, is significant and therefore reduction in degradation rates is critical for the economic success of SOFCs in residential applications. However, this example gives only an estimate of the financial difference. The truth is, that neither in household nor in industrial applications is it acceptable to exchange the SOFC every two years or even earlier. In such a case the reputation of the producer of heaters, power plants or cars will be strongly dam-aged and will cause severe problems with the overall business of the respective company.

Progress to date

Although the first technical objective, the use of commercially available ferritic steels, sounds simple, the first year of the project has shown that it is much more difficult than expected because either applicable interconnect materials are often only available when an order of more than 50 tons is placed or the geometry of the available semi-finished products is not suitable for the tasks in the project. From the 6 steels used in the project, it is expected that one or two steels will be good candidates to achieve low ohmic resistances due to the low contents of Al and Si in the alloy.

Combinations of interconnect/ceramic contact layers have been tested electrochemically and in oxidation exposure experiments. Apart from the steels two of the considered contact layer materials show a smaller reaction zone with these two steels than the other contact materials (see Figure 1). During the coming months it will be decided with which materials a final long-term stack test will be performed.

Currently the electrochemical operating conditions for the ECN cells are varied and especially for the anode compartment, the use of different fuel gases and fuel utilisation are of special concern. Three different anode-supported cells were investigated by mechanical methods to determine the fracture stress and the critical defect sizes that may lead to failure. Significant differences by a factor two in the modulus of rupture were found. Initial model stack tests showed that the curvature of the cells does not change as long as the sealing material remains intact.

INFORMATION

References: ENK5-CT-2000-00308

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- Forschungszentrum Jülich (D)
- Energieonderzoek Centrum Nederland (NL)
- Risø National Laboratory (DK)
- Haldor Topsøe (DK)
- Rolls-Royce (UK)

Contact point:
Frank Tietz
Tel: +49-2461-615007
Fax: +49-2461-612455
f.tietz@fz-jülich.de

EC Scientific Officer:
Antonio Paparella
Tel: +32-2-2957240
Fax: +32-2-2964288
antonio.paparella@cec.eu.int

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