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Self-healing, isolating coatings for solid oxide fuel cells (SOFC):

Damage mechanisms under high temperature conditions and optimization

Begin: 01.04.2012
End: 31.03.2015

Aim

The aim of this project is the improvement of the reliability of solid oxide fuel cells (SOFC) during operation. Thermal cycling with high heating and cooling rates imply extreme demands for the material and the components. Especially the durability of the fuel cell is influenced heavily.

The components are connected with a seal [figure 1 (red)], which consists of a ceramic-metal coating system. The focus of our investigations is directed towards the creation and growing of defects, as cracks, pores or delaminations in the ceramic metal interface. In Figure 1 we see the planar design of the solid oxide fuel cell. The overall setup of the fuel cell consists of:

- interconnect plate
- window frame
- power generating cell
- seal (red)

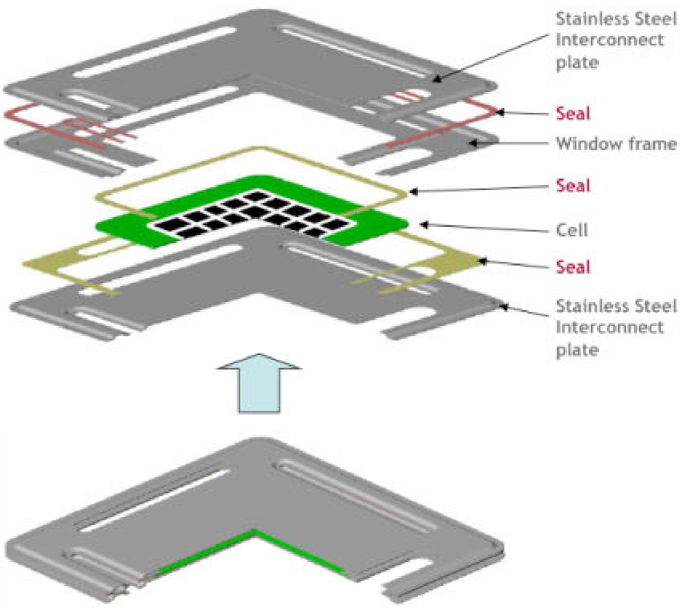

Figure 1: solid oxide fuel cell (planar design) [www.sae.org]

Under operation conditions the defects tend to failure of the fuel cell. Because of the different thermal expansions coefficients and the frequent temperature cycles with a temperature maximum of 800 °C the individual components are thermomechanical high loaded. Especially the seal between the interconnect plates is stressed.

The ceramic coating of the seal is produced by plasma spraying. This process leads to a complex microstructure due to the rapid cooling of the molten ceramic particles on the surface.

Figure 2 shows such a characteristic microstructure of a plasma sprayed coating with defects. In this 200 µm thick ceramic coating we see pores and cracks. These defects have a critical influence on the durability of the fuel cell, because they are starting points of macrocracks in the coating and potentially lead to failure.

The ceramic-metal coating system has two main tasks:

- separation: the fuel (e. g. hydrogen) and the air required for the chemical reaction have to separate from each other.
- isolation: the coating has to isolate permanent during thermal cycling. Thereby an electrical short-circuit can't occur leading to a complete failure of a fuel cell.

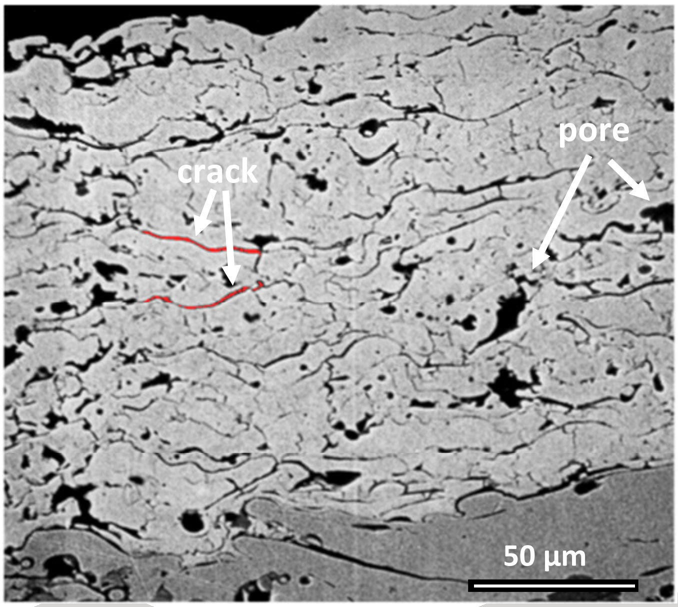

Figure 2: microstructure of a plasma sprayed coating [Nicholls et al. (2002)]

A concept is to inhibit the growth of existing cracks, which are introduced by the manufacturing process as well as to reduce the creation of new cracks with usage of self-healing effects. These effects will be investigated with experiments. The findings of the experiments contribute to understanding.

Approach

We develop a realistic microstructural model, which represents some critical mechanical states for the coating. It contributes to better understanding of the damage mechanisms. These findings are used to improve the damage model iteratively.

A realistic simulation we require the thermo-mechanical properties as well as the thermo-physical properties of the ceramic. Therefore we conduct measurements of the properties additionally.

We profit from the self-healing effect by introducing a self-healing component. The effect reduces the crack creation and the growth. We investigate the self-healing effect with experiments and numerical simulation, too.

Finally the coating system will be optimized with the focus on the improvement of the crack development. Therefore we expect improvement of the durability of the fuel cell.

We use the finite-element-method (FEM) to simulate the material and the component behaviour. Therefore we utilize the commercial FEM solver ABAQUS and the software Digimat. In cooperation with the project partners we transfer the microstructure damage models to the macromechanical behaviour of the components.

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In particular we emphasize the following aspects in this section of the project:

- identification of the critical damage mechanisms
- development of a powerful damage model with iterative optimization
- thermo-mechanical microstructure simulation
- optimization of the fracture mechanical properties
- comparison of the simulation with experimental results
- coupling of the modified damage model on different length scales
- application of the modified damage model in close cooperation with partners

Partners

This project is realized in cooperation with partners from industry and research.

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