Relationships between structures and performance of SOFC anodes - DTU Orbit (10/03/2019)

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The nickel-YSZ cermet of the state-of-the-art anode-supported solid oxide fuel cell (SOFC) degrades upon redox cycling. The degradation is a critical issue for the commercialization of the technology.

Nickel-YSZ cermets with variable composition and microstructure were examined during redox cycling to obtain knowledge of the degradation mechanism, and to identify parameters and characterization tools to improve the cermet. The investigation techniques included direct observations of the microstructure (light microscopy, scanning electron microscopy, environmental scanning electron microscopy, image analysis), bulk measurements (porosity, dilatometry, mechanical properties), measurements of the electrical performance (direct current conductivity, impedance spectroscopy), measurements of the redox kinetics (thermo gravimetric analysis, synchrotron), and application of simple models of the layered system.

A model of the redox mechanism on the microstructural level was described. The degradation related to redox cycling was ascribed to a dynamic reorganization of the Ni/NiO phase, when in the reduced state and upon re-oxidation. The redistribution generated fractures in the YSZ matrix, and bulk expansion of the cermet structure upon oxidation. The bulk expansion promoted cracking of the electrolyte. The redistribution of the reduced nickel phase was observed to occur as rounding of the particles, and nickel sintering. The degree of sintering depended on the temperature, the composition of the ceramic component, and possibly on the local porosity. The redistribution of the NiO phase upon oxidation was seen to depend on the kinetics and the local porosity. At higher temperatures the oxide growth involved fragmentation of the particles. At lower temperatures the growth occurred in the form of an external oxide peel.

The mechanical strength of the ceramic component was indicated as a technological potential parameter for improving the redox stability. However, considerable strengthening was indicated to be required. Strengthening that will result in a reduction of the bulk expansion upon re-oxidation with a factor of two was estimated.

Modification of the cermet composition with additives was indicated as a possibility for improving the redox stability. Significant strengthening and reduction of the nickel sintering were indicated achievable with additives. However, further experimental work will be required to discover the full potential of the application of additives. The future work will be empirically based, or include detailed descriptions of the relationships between microstructural parameters and the cermet bulk properties.

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