QUANTITATIVE TRANSPORT NETWORK COMPARISON OF DIFFERENT LOCATIONS IN A TESTED SOLID OXIDE ELECTROLYSIS CELL

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Summary: Solid oxide electrolyses cells are dependent on the transport of gas, electrons and ions through three separate intertwined phase networks for their operation. The present study analyses the characteristics of these transport networks at four different locations in a tested electrolysis cell. The results show significant differences in the quality of the transport network at the gas inlet site compared to the gas outlet site.

1. INTRODUCTION

Energy devices such as solid oxide electrolysis cells (SOEC), fuel cells and batteries are promising technologies for conversion and storage of energy in a future based on sustainable energy. In the case of an SOEC the device consists of two electrodes and an electrolyte. The electrodes are typically two-phase, porous systems. The two solid phases are responsible for the conduction of electrons (Ni) and ions (YSZ) and the pore phase allows transport of gaseous reactants and products to and from the electrochemically active sites at the triple phase boundaries (TPB). The chemical reactions can only take place at a TPB and only if all three phases form connected pathways to their respective source and destination (e.g. the electrolyte, gas supply and current collector). The performance of an SOEC is strongly dependent on the density of TPBs and on how easily ions, electrons, reactants and products can be transported to and from the TPBs. The accurate characterization of the pathways to and from the TPBs is thus a strong tool for studying microstructure related degradation phenomena, optimizing production recipes, and linking the electrochemical performance to the microstructure.
In this work we study differences in the microstructure transport properties as a function of spatial location relative to the gas inlet in a tested solid oxide electrolysis cell. Many bulk properties such as volume specific interface areas between faces and TPB density can be estimated from polished cross-sections. However, pathway specific properties require 3D image data to be analysed. We apply different complementary pathway analysis methods to characterize the network differences in the microstructure at different sites in an SOEC.

2. EXPERIMENTAL

The SOEC Ni/YSZ electrode selected for this 3D microstructure comparison was from a single repeating unit cell test [1]. The cell was run for 900 hours at 850 °C with 24l/h 50% H^2 + 50% H^2O supplied to the hydrogen electrode compartment at -1.5A/cm^2.
3D image data was collected at 4 sites in the Ni/YSZ electrode; gas inlet, gas outlet, centre and under the gas sealing. The sample from under the gas sealing was included as an internal reference since this site was exposed to temperature but not gas or current. Figure 1 shows a slice from each of the different sites along with a 3D rendering of the gas inlet dataset.
The 3D data was collected by focused ion beam (FIB) tomography using a Zeiss 1540 XB microscope at a voxel size of 25 x 25 x 36 nm. The image data was acquired with the SEM column while milling with the FIB. This simultaneous acquisition strategy was found to suppress the grain orientation contrast in the Ni phase, enabling easier segmentation of the data.
Finite element method software [2] was used to calculate the effective transport properties through each phase

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summarised by the tortuosity factor. Network properties like the pathway tortuosity and pathway diameter are usually calculated as a property between two opposing edges of a volume. In the present work we extract these quantities on a per-active-site basis [3], thus obtaining detailed information on the distances to and from the active sites through each phase and the thickness of the pathways through which they can be reached. The two different approaches complement each other well as the tortuosity factor [2] encompasses all microstructure properties whereas the geometric pathway results [3] provide site specific information and attempts to geometrically explain the cause of a given tortuosity factor value through the concepts of tortuosity and constrictivity.

3. RESULTS

The transport network analyses show a severe reduction in the quality of the transport network at the centre of the cell and at the gas inlet site compared to the gas outlet and the reference site: 1) A significantly lower fraction of percolating TPB sites are observed, mainly caused by a reduction in Ni phase percolation. 2) A significantly higher tortuosity factor is observed due to both longer transport pathways and thinner bottlenecks.

References

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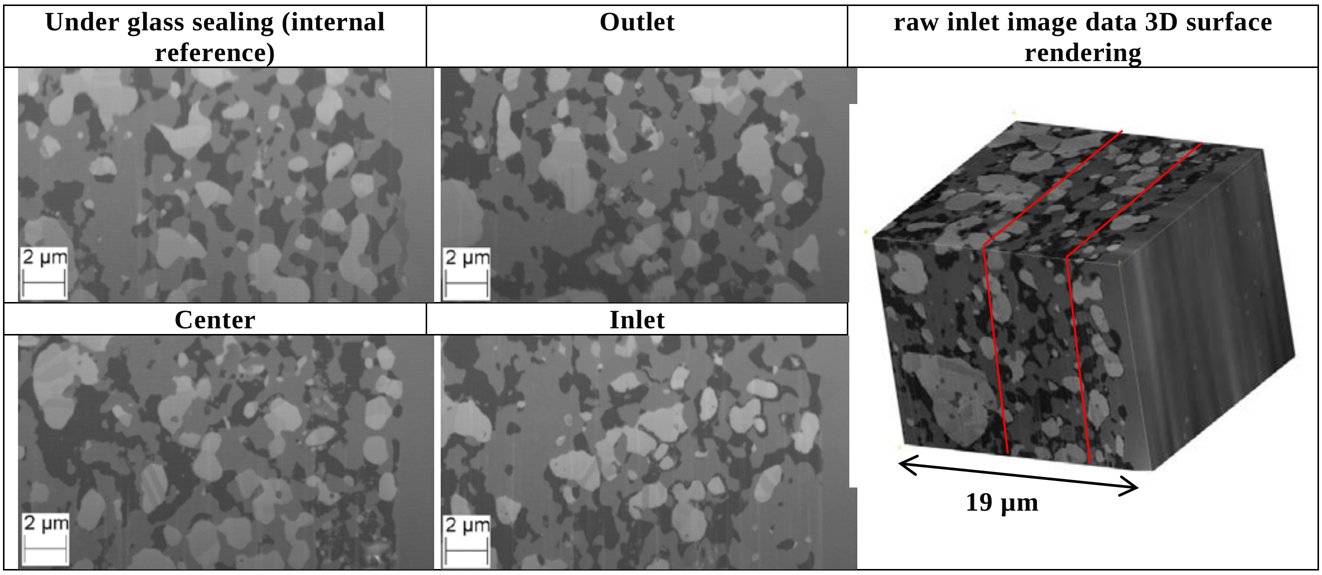

Figure 1: (left) A single raw slice from each of the four datasets. (right) A 3D surface rendering of the raw FIB tomography image data from the inlet site. The red lines indicate the part of the active electrode which was compared between each site. In all images the dark regions are pores (gas transport), the gray regions are YSZ (ion conduction), and the white regions are Ni (electron conduction).