Electromotive Potential Distribution and Electronic Leak Currents in Working YSZ Based SOCs

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Electromotive potential distribution and electronic leak currents in working YSZ based SOCs

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A solid electrolyte will always possess a finite electronic conductivity. This given rise to worries about the introduction of high partial pressures inside and about too high leak currents through the yttria stabilized zirconia (YSZ) electrolyte of the solid oxide cell (SOC). Especially, problems have been predicted for the case of solid oxide electrolyser cell (SOEC).

The necessary equation for calculating the course of the electromotive potential across an SOC was established in a previous paper [1], and using the data for YSZ reported by Park and Blumenthal [2], the distribution of both the electromotive, the Galvani potentials and oxygen partial pressure across the cell was outlined in general.

This paper gives calculations for cells similar to the Risø DTU type of cells using data from cells measured in solid oxide fuel cell (SOFC) mode [3]. The polarization resistances, R_p, are taken as independent of current density. This is a fair approximation for these cells. Further, 1 atm pressure, pure oxygen on the oxygen side, and a mixture of 50 % steam, 50 % hydrogen on the hydrogen electrode were assumed. Then, partly based on data from [3] the following numbers were used as basis for the calculations: At 850 °C $R_{p,Ni\text{-}YSZ} = 0.05\ \Omega\ cm^{-2}$, $E_a = 0.8$ eV, and $R_{p,LSM\text{-}YSZ} = 0.07\ \Omega\ cm^{-2}$, $E_a = 1.1$ eV. All YSZ data were taken from [2]. The varied parameters were cell voltage, temperature, and electrolyte thickness.

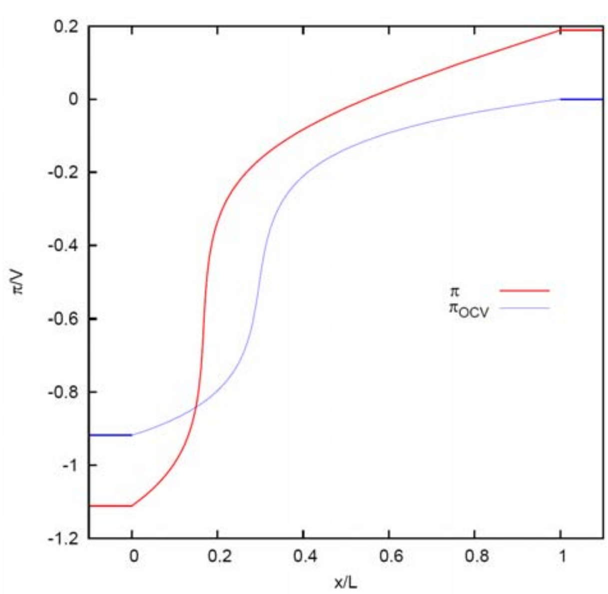

Figure 1: Electromotive potential, π, as function of relative distance from the interface between the negative electrode and the electrolyte in a cell operating in SOEC mode at the thermo-neutral cell voltage of 1.3 V compared to open circuit conditions at 1000 °C. x/L = 1 is the interface to the oxygen electrode. The electrolyte thickness was set to 200 µm, which gave an oxide ion current density of -2.1 A cm^{-2}. The electron leak current density is ~ 10^{-4} A cm^{-2} under the SOEC operation condition.

Apart from the curves of electromotive potential, the cell current density (the oxide ion current density) and the electronic leak current densities were calculated.

Figs. 1 and 2 show two examples. The calculated electromotive potential as function of the distance from the interface between the Ni-YSZ (the H_2O/H_2) electrode and the electrolyte is given. The potential of the LSM-YSZ (O_2) electrode is taken as zero, i.e. as the reference.

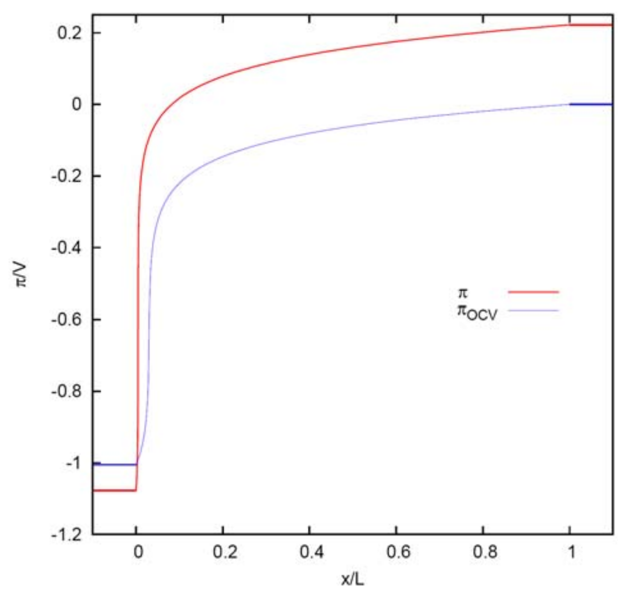

Figure 2: Electromotive potential, π, plotted like in Fig. 1 for 700 °C. The electrolyte thickness was set to 20 µm, which gave an oxide ion current density of -0.12 A cm^{-2}. The electron leak current density is ~$4\cdot10^{-6}$ A cm^{-2} under the SOEC operation at 1.3 V.

The electromotive potential, which reflects the local concentration of n and p (free electrons and holes), and thus the "stability" of the YSZ, follows smooth curves, and does not assume any critical value. The electrolyte part with the π-values left of the inflection points is predominantly n conductor and on the right side predominantly p conductor. The cell current densities look realistic, and most importantly, the electronic leak currents stay at insignificant low values compared to the current density of the cell. The calculated parameters as functions of cell voltage, temperatures and electrolyte thickness will be given in the paper.

Acknowledgements
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