

Modeling of Anode-supported SOFCs Operating with H₂ and CO Feed Mixtures

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Anode-supported Solid Oxide Fuel Cells (SOFCs) are a promising technology for stationary application in the mid-term future. The reaction kinetics of anode-supported design are more suitable for lower temperature operation than any other SOFC designs. Lower temperature operation allow for lower material and manufacturing costs and thus easier commercialization. In comparison to other fuel cell types, SOFCs have a significant advantage in that it may allow for internal reforming of hydrocarbon-based fuels such as natural gas, biogas and coal gas. For effective use hydrocarbon fuels must be partially reformed to H₂ and CO in an external reformer or cell itself. Although CO can be oxidized electrochemically in SOFCs, its cell voltage and power density are not as high as those obtained from the H₂ electrochemical reaction (1). This is because CO diffuses slower than H₂ through thick porous anode to the reaction sites at the anode/electrolyte interface. This results in decreasing the actual cell voltage and power density when CO concentration increases in the feed stream. The objective of this paper is to present a one-dimensional model and to investigate the effect of CO/H₂ ratio on the electrochemical oxidation rate. Furthermore, this model is able to predict cell voltage and electrical power density for various feed gas compositions.

The equivalent circuit of the cell used in this model is illustrated in Figure 1. The electrochemical reactions of H₂ and CO take place at the same time, and thus the equivalent circuit model of these reactions are connected in parallel. Each of them incorporates its reversible cell voltage ($E_{r(H_2)}$, $E_{r(CO)}$), activation polarization ($V_{Act,A(H_2)}$, $V_{Act,A(CO)}$) and concentration polarization ($V_{Conc,A(H_2)}$, $V_{Conc,A(CO)}$). The ohmic polarization (V_{IR}) at the electrolyte and the activation polarization at the cathode ($V_{Act,C}$) are connected in series as this polarization affects the oxidation of H₂ and CO equally. The concentration polarization at cathode side is assumed negligible. All activation polarizations are modeled from equations adapted from Nagata *et al.* (2). The concentration polarization is defined as the difference between the ideal local reversible cell voltage and the real reversible cell voltage. This can be calculated using the molar concentrations of reactant and product gases at the anode/electrolyte interface and those at the bulk (2,3). The mass transport of multicomponent system (H₂-H₂O-CO-CO₂) inside the porous SOFCs anode is simulated using the dusty-gas model coupled with the Graham's law of diffusion to obtain the gas concentrations at anode/electrolyte interface (4).

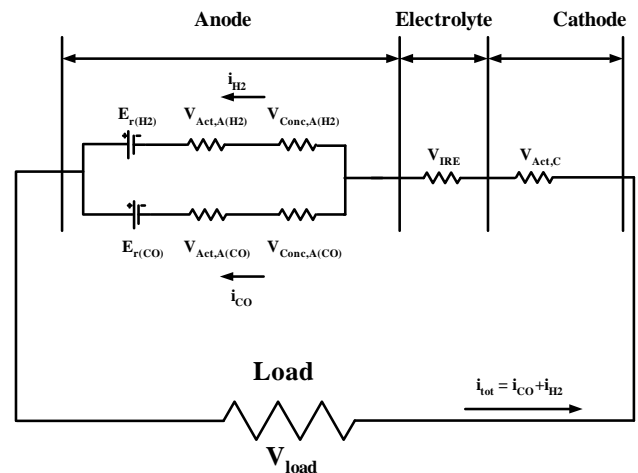


Figure 1. Equivalent circuit of cell.

Model results reveal that the ratio of electrochemical oxidation rate between H₂ and CO increases as the cell voltage declines and as the amount of H₂ increases. For the same amount of H₂ and CO, the electrochemical oxidation rate for H₂ is found to be 1.1-2.6 times at 800 °C, and 2-2.6 times for 1000 °C greater than that of CO. This result agrees with the experimental investigation from Matsuzaki *et al.* (1). It was also found that the cell voltage and power density decrease as the concentration of CO increases. Furthermore, the effect of fuel gas compositions is more crucial at 800 °C than at 1000 °C. This is because the concentration polarization which is sensitive to the fuel gas composition is a more dominant factor in cell voltage and power density at 1000 °C than at 800 °C.

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REFERENCES

1. Y. Matsuzaki, M. Hishinuma, and I. Yasuda, in *Proceedings of Solid Oxide Fuel Cell VI*, S. C. Singhal and M. Dokiya, Editors, PV 99-19, p. 560, The Electrochemical Society Proceedings Series, Pennington, NJ (1999).
2. S. Nagata, A. Momma, T. Kato and Y. Kasuga., *J. Power Sources*, **101**, 60 (2001).
3. S. H. Chan, K. A. Khor and Z. T. Xia, *J. Power Sources*, **93**, 130 (2001).
4. R. Krishna and J. A. Wesselingh, *Chem. Eng. Sci.*, **52**, 861 (1997).