Investigation of H_2, CO, and Syngas Electrochemical Performance using Ni/YSZ pattern anodes

Weifang Yao, Eric Croiset
Department of Chemical Engineering,
University of Waterloo
200 University Ave. West
Waterloo, ON N2L 3G1, Canada

Introduction

Solid oxide fuel cell (SOFC) is a promising power generation technology due to its high efficiency and low emissions [1]. Moreover, SOFC can operate under a wide range of fuels, such as hydrogen, carbon monoxide and hydrocarbons [2]. Most modeling works have assumed that CO is primarily consumed through the water-gas shift reaction. This is probably a valid assumption for high temperature cells, but for low temperature SOFC, direct electrochemical oxidation of CO could become more important. Investigation of H_2 and CO electrochemical oxidation separately can help interpret the reaction mechanism and pathways of syngas oxidation. Furthermore, it helps understand the electrochemical performance of hydrocarbon fuels on SOFC anodes [3]. Since Ni/YSZ pattern anodes have simplified 2-D structure and well defined triple phase boundary length, they are ideally suited to study H_2 and CO electrochemical oxidation. Concerning H_2 electrochemical oxidation, there is currently no agreement in the literature regarding activation energy, charge transfer coefficient, hydrogen and water reaction order. Moreover, the qualitative value of polarization resistance is quite different from one research group to another. Only a few studies were performed for CO oxidation. Therefore, mechanistic details of H_2 and CO oxidation are still not fully resolved [4].

In this work, we investigated the electrochemical performance of H_2, CO, and syngas using Ni/YSZ pattern anodes.

Material and Methods

Ni/YSZ pattern anodes with Ni thickness of 1 μm were fabricated on 8 mol% Y_2O_3 stabilized ZrO_2 single crystal discs. A photolithography process with bi-layer resist system was used for constructing Ni patterns on YSZ surface. Platinum (Pt) cathode and Pt reference electrodes with thickness of 100 nm were prepared by DC magnetron sputtering. The Pt cathode (not patterned) was placed symmetrically to the pattern anode on the opposite side of the YSZ single crystal. The composition changes of different gases were achieved through mass flow controllers. N_2 was used as balance gas. The cell performance was evaluated by electrochemical impedance spectroscopy (EIS) in different gas environments.

Results and Discussion

The Ni/YSZ pattern anodes were first electrochemically tested in humidified H_2 (3% H_2O) at 750°C for about 25 hours in order to stabilize the Ni pattern structure and performance (See Fig. 1).

Fig. 2(a) describes the impedance spectra changes upon varying the ratio of H_2 to CO. Polarization resistance (R_p) increases when increasing the amount of CO (See Fig. 2(b)). When the ratio of pCO/pH_2 is less than 1, the polarization resistance of H_2 and CO mixture is only slightly higher than that of pure H_2 (<14.5%). However, when the ratio of pCO/pH_2 is over than 1, the increase of R_p becomes faster, and the value of R_p in CO is 1.67 times than that in H_2. Also, the similar shape of impedance spectra for H_2 and CO (Fig. 2(a)), and polarization resistance of similar order of magnitude indicates that the electrochemical oxidation of H_2 and CO may proceed in a similar way [5].

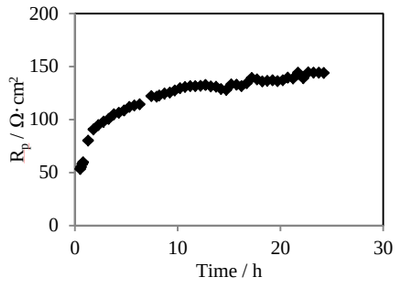
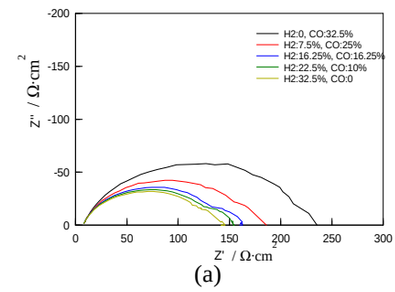
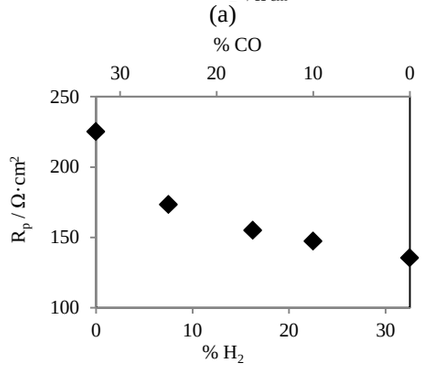


Fig.1. R_p changes with time in the following conditions: $pH_2=5\times10^4$ Pa (20%), $pH_2O=3\times10^3$ Pa (3%), T=750°C.



(a)



(b)

Fig. 2 (a) Impedance spectra changes with varying the ratio of H_2 and CO, (b) R_p changes with H_2 and CO composition, T=750°C.

Conclusion

Ni/YSZ pattern anodes were used to investigate the electrochemical performance of H_2, CO and syngas. The polarization resistance for CO oxidation is about 60-70% higher than for H_2 electrochemical oxidation. The dependence of R_p on H_2 and CO partial pressure follows a non-linear trend where R_p changes moderately for cases were pCO/pH_2 is less than one.

References

[1] N.Q. Minh, T. Takahashi, Science and Technology of Ceramic Fuel Cells, 1st ed., Elsevier Science; 1995, pp. 378.

[2] V. Yurkiv, A. Utz, A. Weber, E. Ivers-Tiffée, H.R. Volpp, W.G. Bessler, Electrochim.Acta, (2011).

[3] A.M. Sukeshini, B. Habibzadeh, B.P. Becker, C.A. Stoltz, B.W. Eichhorn, G.S. Jackson, J.Electrochem.Soc., 153 (2006) A705.

[4] V. Yurkiv, D. Starukhin, H.R. Volpp, W. Bessler, J.Electrochem.Soc., 158 (2011) B5-B10.

[5] A. Utz, A. Leonide, A. Weber, E. Ivers-Tiffée, J.Power Sources, 196 (2011) 7217-7224.