

Proton-conducting solid oxide fuel cells fed by syngas and its degradation mechanisms

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Introduction

Solid oxide fuel cell (SOFC) has been intensively studied over the last several decades since it exhibits higher efficiency, lower CO_2/NO_x emission than internal combustion engine and comparable fuel diversity¹. Recently, increasing attentions have been paid to the development of SOFC using proton conducting electrolyte (PC-SOFC). A promising advantage of PC-SOFC relative to the SOFC using oxygen ionic conducting electrolyte lies in its higher theoretical efficiency since the anode fuel will not be diluted.

PC-SOFC can also be fed by hydrocarbons through internal steam reforming and/or water gas shift reaction, which will produce hydrogen². However, performance of PC-SOFC fed by carbon-containing fuels is significantly lower than expected value. A general understanding of the fuel cell degradation reasons was attributed to increased fuel cell ohmic resistance, higher concentration overpotential and carbon deposition, neither of these speculations had been investigated experimentally in details. Herein, we studied the negative influence of CO on PC-SOFC performance and proposed a 3-stage CO poisoning mechanism.

Experimental

Both $\text{BaCe}_{0.7}\text{Zr}_{0.1}\text{Y}_{0.2}\text{O}_3$ (BZCY) electrolyte and $\text{BaPrCo}_2\text{O}_5$ (BPC) cathode materials were synthesized via citrate-nitrate auto combustion method. After auto combustion, the as-prepared powders were calcined at 1100°C for 10 h in air to achieve a single phase oxide. For single cell fabrication, a powder mixture of BZCY, NiO and corn starch was pressed into pellets and sintered to form strong anode substrates. Then NiO/BZCY anode functional layer and BZCY electrolyte were spin coated on the strong substrate sequentially before 4 h densification at $1,420^\circ\text{C}$. Finally, BPC/BZCY cathode layer was coated onto the dense electrolyte, followed by sintering at $1,000^\circ\text{C}$ for 2 h.

Results and discussions

PC-SOFC button cell demonstrated power densities of 192 mW cm^{-2} and 506 mW cm^{-2} in $10\% \text{ H}_2 + \text{N}_2$ and pure H_2 , respectively (Fig.1). However, after the cell was operated in $10\% \text{ H}_2 + \text{CO}$ for 3 h under potentiostatic mode, dramatic performance decrease was observed and the power density dropped from 168 mW cm^{-2} to below 50 mW cm^{-2} (Fig.1). This degradation, which was attributed to CO poisoning, was fully recoverable when CO was removed away from the feed and its magnitude was strongly influenced by cell operating voltage (OCV or potentiostatic).

Generally, we proposed 3 stages of CO poisoning in PC-SOFC working under potentiostatic mode (Fig. 2).

After the introduction of CO, there was an initial sharp current drop instantly, which can be quickly recovered once CO was turned off. The 2nd stage CO poisoning took hours to reach equilibrium and was more serious when PC-SOFC was discharging. Nevertheless, this poisoning was also fully reversible when CO was replaced by N_2 . The 3rd stage degradation was caused by carbon deposition resulting in anode structure disintegration, which was an irreversible process.

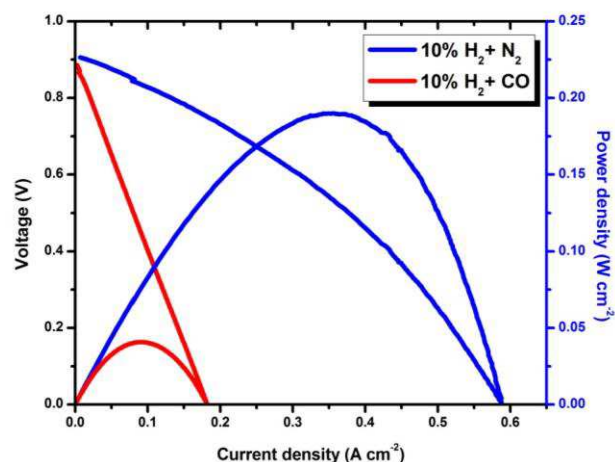


Figure 1. Power density comparison for PC-SOFC fed by $10\% \text{ H}_2 + \text{N}_2$ and $10\% \text{ H}_2 + \text{CO}$ at 700°C .

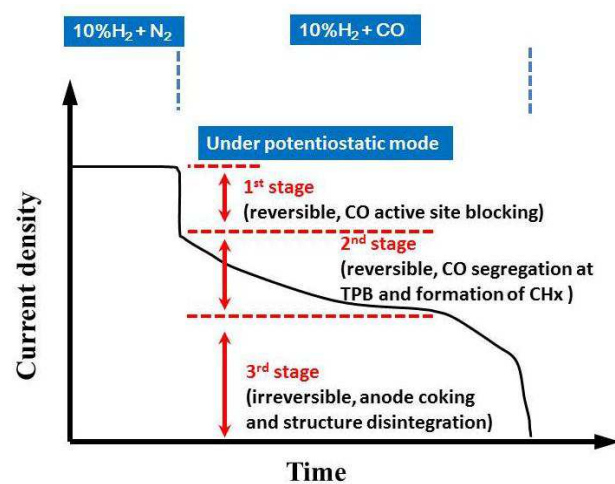


Figure 2. 3-stage CO poisoning of PC-SOFC under potentiostatic mode.

References

- [1] E. P. Murray, T. Tsai, S. A. Barnett, *Nature* **400**, 649-651 (1999).
- [2] M. Ni, D. Y. C. Leung, M. K. H. Leung, *J. Power Sources* **194**, 1226-1227(2009)