Performance and Durability of Single HT-PEM fuel cell with bare and CrN/Cr-coated 316L stainless steel bipolar plates

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Keywords: Metallic Bipolar Plate, Coating, HT-PEMFC, Fuel Cell, Corrosion

High-temperature polymer electrolyte membrane fuel cells (HT-PEMFCs) operate in the range of 120-180 °C and currently employ phosphoric acid-doped polybenzimidazole membranes. This, in turn, represents a fairly aggressive environment for the components of a fuel cell [1]. For this reason, bipolar plates are currently made of graphitic composite materials. Although these show long-term stability, they exhibit high mass and volume, as well as requiring a high manufacturing effort. Therefore, metallic materials are promising candidates for bipolar plates [2]. The advantages they offer include enhanced volumetric and gravimetric power density for stacks, increased ductility, high mechanical stability and the capacity for low-cost mass production. Due to the corrosion of the metals, it is not feasible to employ bare, commercially-available stainless steels or Ni-based alloys as metallic bipolar plates for HT-PEMFC applications. One possibility to reduce the corrosion rate while retaining the benefits of metals could be applying conductive and inert coatings [3].

For coatings without self-healing ability, localized corrosion should occur at the damaged site and continuously corrode the substrate under the coating. Self-healing ability can be given to films by introducing a metallic component into them: the oxidation of the metallic component will heal flaws in the films [4]. In our previous work [5], we demonstrated the good performance of CrN/Cr coatings inside the simulated cathodic environment of HT-PEMFCs. This is due to the relatively high potential and presence of oxygen, leading to the oxidation of chromium at damaged sites, thus providing sufficient corrosion resistance to the cathodic HT-PEFC environment.

In this study, the single cell performance with the CrN/Cr-coated stainless steel bipolar plate was examined under galvanostatic operation at 0.2 A cm^{-2} for 1000 h by means of polarization tests and electrochemical impedance spectroscopy (EIS). The results were compared with those of a reference cell with bare SS316L bipolar plates. Additionally, ex-situ characterizations using SEM+EDX and ICP-OES were carried out in order to investigate the metallic surface, corrosion products and corresponding dissolved ion species in the membrane electrode assembly (MEA). The interfacial contact resistances (ICR) of the bipolar plates before and after 1000 h of tests were also examined. Based on this research, we succeeded for the first time in clarifying the effect of the corrosion of metallic bipolar plates on the degradation mechanisms of HT-PEMFCs. The degradation decreased from ca. 16% with bare metallic bipolar plates to almost zero with CrN/Cr-coated metallic bipolar plates following the 1000 h durability test.

Acknowledgements
R. Li and Y. Cai acknowledge the China Scholarship Council for their support.

REFERENCES

1. C. Hartnig, and T.J. Thomas. Electrochimica Acta 56 4237-4242 (2011).
2. R. Li, Y. Cai, K. Wippermann, W. Lehnert. Journal of The Electrochemical Society, 165(10), C681-C688 (2018).
3. V. Weissbecker, K. Wippermann, and W. Lehnert. Journal of The Electrochemical Society, 161(14), F1437-F1447 (2014).
4. M. Yasuda, N. Akao, N. Hara, K. Sugimoto. Journal of The Electrochemical Society, 150(10), B481-B487 (2003).
5. R. Li, Y. Cai, K. Wippermann, W. Lehnert. ECS Transactions, 85(13), 585-598 (2018).