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Effects of Bipolar Plate Coating Layer on Performance Degradation of High-Temperature Proton Exchange Membrane Fuel Cell

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Abstract : Over the past few centuries, human requirements for energy have been met by burning fossil fuels. However, exploiting this resource has led to global warming and innumerable environmental issues. Thus, finding alternative solutions to the growing demands for energy has recently been driving the development of low-carbon and even zero-carbon energy sources. Wind power and solar energy are good options but they have the problem of unstable power output due to unpredictable weather conditions. To overcome this problem, a reliable and efficient energy storage sub-system is required in future distributed-power systems. Among all kinds of energy storage technologies, the fuel cell system with hydrogen storage is a promising option because it is suitable for large-scale and long-term energy storage. The high-temperature proton exchange membrane fuel cell (HT-PEMFC) with metallic bipolar plates is a promising fuel cell system because an HT-PEMFC can tolerate a higher CO concentration and the utilization of metallic bipolar plates can reduce the cost of the fuel cell stack. However, the operating life of metallic bipolar plates is a critical issue because of the corrosion phenomenon. As a result, in this work, we try to apply different coating layer on the metal surface and to investigate the protection performance of the coating layers. The tested bipolar plates include uncoated SS304 bipolar plates, titanium nitride (TiN) coated SS304 bipolar plates and chromium nitride (CrN) coated SS304 bipolar plates. The results show that the TiN coated SS304 bipolar plate has the lowest contact resistance and through-plane resistance and has the best cell performance and operating life among all tested bipolar plates. The long-term in-situ fuel cell tests show that the HT-PEMFC with TiN coated SS304 bipolar plates has the lowest performance decay rate. The second lowest is CrN coated SS304 bipolar plate. The uncoated SS304 bipolar plate has the worst performance decay rate. The performance decay rates with TiN coated SS304, CrN coated SS304 and uncoated SS304 bipolar plates are 5.324×10^{-3} % h^{-1}, 4.513×10^{-2} % h^{-1} and 7.870×10^{-2} % h^{-1}, respectively. In addition, the EIS results indicate that the uncoated SS304 bipolar plate has the highest growth rate of ohmic resistance. However, the ohmic resistance with the TiN coated SS304 bipolar plates only increases slightly with time. The growth rate of ohmic resistances with TiN coated SS304, CrN coated SS304 and SS304 bipolar plates are 2.85×10^{-3} h^{-1}, 3.56×10^{-3} h^{-1}, and 4.33×10^{-3} h^{-1}, respectively. On the other hand, the charge transfer resistances with these three bipolar plates all increase with time, but the growth rates are all similar. In addition, the effective catalyst surface areas with all bipolar plates do not change significantly with time. Thus, it is inferred that the major reason for the performance degradation is the elevated ohmic resistance with time, which is associated with the corrosion and oxidation phenomena on the surface of the stainless steel bipolar plates.

Keywords : coating layer, high-temperature proton exchange membrane fuel cell, metallic bipolar plate, performance degradation

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