Proceedings of the 10th World Congress on Mechanical, Chemical, and Material Engineering (MCM'24)
Barcelona, Spain –August 22-24, 2024
Paper No. HTFF 116
DOI: 10.11159/htff24.116

Performance Improvement of Magnetic Field Applied Proton Exchange Membrane Water Electrolysis under Various Operating Conditions

Jun Yeob Chung[1], Seong Su Park[1], Jeongwoo Roh[1], Yongchan Kim[1,*]
[1]School of Mechanical Engineering, Korea University
145, Anam-ro, Sungbuk-gu, Seoul, 02841, Republic of Korea
jjy7564@gmail.com; kpsungsu@naver.com; roh96@korea.ac.kr; yongckim@korea.ac.kr
* Corresponding author

Extended Abstract

Water electrolysis systems are regarded as a promising green hydrogen production method owing to their high current density and eco-friendliness [1]. Among them, proton exchange membrane water electrolysis (PEMWE) systems coupled with renewable energy sources show potential to be utilized because of their fast response to the dynamic change in climate conditions [2]. Despite these advantages, there are still limitations in the commercialization of PEMWE systems because the production costs per hydrogen mass are significantly higher than those per fossil fuel mass. Additionally, the efficiency of PEMWE systems is not high enough owing to sluggish oxygen evolution reactions (OERs) [3]. For these reasons, it is necessary to reduce the hydrogen production cost of PEMWEs and enhance the OER performances. Many studies related to catalysts, membranes, and flow channels have been conducted to reduce OER-related losses [3,4]. However, these efforts are faced with critical bottlenecks concerning the complicated and high costs of the fabrication methods. In this regard, it is essential to introduce a novel way to improve the OER performance.

In this study, magnetic fields (MFs) are introduced to enhance the OER performance of PEMWEs. The current densities of normal PEMWEs were compared with those of MF-applied PEMWEs (MF-PEMWEs) through experiments under various operating conditions. The experiments were conducted with a unit cell that has an active area of 9 cm^{-2}. Membrane electrode assemblies (MEAs) were fabricated using the catalyst-coated membrane method, employing 2.5 mg_{IrO2} cm^{-2}, 0.4 mg_{Pt} cm^{-2}, and Nafion 115. Titanium fiber felts and microporous layer-coated carbon papers were chosen for the gas/liquid transport layers at the anode and cathode, respectively. Titanium bipolar plates with 3-line serpentine flow channels were used on both anode and cathode sides. Operating temperatures were set to 40, 60, and 80 °C, and voltages were changed from 1.5 to 1.9 V within 5 steps. The water flow rate and pressure were fixed at 4 ml min^{-1} cm^{-2} and 1 atm, respectively. MF densities perpendicular to the MEA surfaces were applied to PEMWEs using permanent magnets. As a result, significant performance improvements in MF-PEMWEs against normal PEMWEs were observed, particularly in the activation loss dominant area. The current density of MF-PEMWEs improved by 13.5% compared with that of normal PEMWE at a voltage of 1.5 V and cell temperature of 40 °C. This was because the MFs enhanced the detachment of oxygen from the three-phase boundary of anode MEA surfaces to increase the OER performances. Additionally, MF effects decreased with increasing the cell temperature from 40 to 80 °C owing to weakened MF strengths caused by disturbed magnetic arrangements in permanent magnets. Therefore, it is recommended to operate MF-PEMWEs under low-temperature and activation loss dominant conditions to maximize the MF effects for improving the hydrogen production rate.

References

[1] S. S. Kumar and V. Himabindu, "Hydrogen production by PEM water electrolysis–A review," Mater. Sci. Energy Technol., vol. 2, no. 3, pp. 442–454, 2019.
[2] J. Gong, C. Sun, H. Shi, and W. Tan, "Response behaviour of proton exchange membrane water electrolysis to hydrogen production under dynamic conditions," Int. J. Hydrogen Energy, vol. 48, no. 79, pp. 30642–30652, 2023.
[3] Q. Feng, G. Liu, B. Wei, Z. Zhang, H. Li, and H. Wang, "A review of proton exchange membrane water electrolysis on degradation mechanisms and mitigation strategies," J. Power Sources, vol. 366, pp. 33–55, 2017.
[4] M. Maier, K. Smith, J. Dodwell, G. Hinds, P. R. Shearing, and D. J. L. Brett, "Mass transport in PEM water electrolysers: A review," Int. J. Hydrogen Energy, vol. 47, no. 1, pp. 30–56, 2022.