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REVIEW ARTICLE

Anion Exchange Membrane Water Electrolyzers: An Overview

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ABSTRACT

The green-H_2 production through water electrolysis from renewable energies is vital in the context of developing a sustainable and cost-effective methodology. Anion exchange membrane water electrolyzer (AEMWE) is considered as a promising energy conversion device, which can be an alternative to fossil fuel-based energyplatforms. AEMWE can employ inexpensive nonprecious metal catalysts and current collectors, which is preferable forpractical applications of this technology. Membrane electrode assemblies (MEAs) for AEMWE plays a significant role forthe hydrogen production efficiency. Thus, understanding the MEA components, operation, and performance is critical forthe development of prominent materials for the AEMWE. In this review, we highlight the performances of the MEAs andtheir components, such as the AEMs and catalysts with a broad discussion of the progress with current status. Additionally,we also have put forward our assessment to lead the way for future research, to commercialize AEMWE as a provenalternative for the cost-effective production of high-purity hydrogen.

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1. Introduction

Achieving carbon neutrality by 2050 is the world's most urgent mission. To achieve this, the dependence on fossil fuels for energy should be reduced, and sustainable energy sources should be explored to meet the growing energy demand. Renewable energy sources, such as solar, wind, tidal, and geothermal energies, are alternate options. However, the localized nature and the associated load fluctuations caused by the intermittent nature of these energy sources prevent their widespread application. Due to its high gravimetric energy density (142 MJ/Kg) and absence of carbon footprint, utilizing H_2 energy is promising and significant under these circumstances (Chatenet et al. 2022; Sun F et al. 2021). Current global H_2 production is approximately 90 megatons per year (Mt/a), and the demand will increase dramatically in the coming decades due to the widespread use of H_2 in the transportation industry (van der Spek et al. 2022). However, current H_2 production relies primarily on reforming fossil fuels, accounting for ~2% of the total global CO_2 emissions (van der Spek et al. 2022). Therefore, developing a sustainable and cost-effective method for massive H_2 production is essential. The New Energy and Industrial Technology Development Organization (NEDO) in Japan aims to reduce the cost of H_2 supply to 30 yen/Nm^3 by 2030 and 20 yen/Nm^3 by 2050 from the current value of 100 yen/Nm^3.

Green-H_2 production through water electrolysis using renewable energy sources is crucial in this context and would reduce CO_2 emissions and climate change (Hubert et al. 2022). Moreover, the high-purity H_2 production is one of the most attractive characteristics of water electrolyzer (WE) technology. Water electrolysis only accounts for 4% of the current total H_2 production. The chemical reaction formula for the electrolysis of water is (Carmo et al. 2013; Shiva Kumar and Himabindu 2019):

$$H_2O \rightarrow H_2 + 1/2\,O_2 \quad (\Delta H^\circ = 285.8\ \mathrm{kJ\ mol^{-1}}) \tag{1}$$

Where the hydrogen evolution reaction (HER) is cathodic, and the oxygen evolution reaction (OER) is anodic. A thermodynamic potential of 1.23 V is required at 25 °C to split water into H_2 and O_2 (Babic et al. 2017; Yu M et al. 2022). Due to activation barriers and various losses like ohmic and mass transfer, the accumulation of generated gas bubbles, requires potential increases to a higher value, reducing the efficiency of the process. Improving system efficiency is a prerequisite for achieving satisfactory H_2 production via water electrolysis, it is also challenging. On the anode and cathode of the WE, high-performance catalysts and ion-conducting membranes are required for satisfactory H_2 production. In addition, efficient system engineering must account for the balance of plant (BOP) for cost-effective technology maintenance.