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Review article

An overview of polymer electrolyte membrane electrolyzer for hydrogen production: Modeling and mass transport

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HIGHLIGHTS

- Not many models have been reported For PEME compared to PEMFC.
- This paper presents the state of art on PEME models.
- It also address the current issues encountered with PEME model.

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ABSTRACT

Polymer electrolyte membrane electrolyzer (PEME) is a candidate for advanced engineering technology. There are many polymer electrolyte membrane fuel cell (PEMFC) models that have been reported, but none regarding PEME. This paper presents state of the art mass transport models applied to PEME, a detailed literature review of these models and associate methods have been conducted. PEME models are typically developed using analytical, semi empirical and mechanistic techniques that are based on their state and spatial dimensions. Methods for developing the PEME models are introduced and briefly explained. Furthermore the model cell voltage of PEME, which consists of Nernst voltage, ohmic over potential, activation over potential, and diffusion over potential is discussed with focus on mass transport modeling. This paper also presents current issues encountered with PEME model.

1. Introduction

A PEME is a device that is based on an electrochemical process and is used for splitting water molecules into hydrogen and oxygen gas [1,2]. The process of PEME is similar to the PEMFC process, but the working principles between the two are opposite [3]. PEMFC can be operated at both ambient and elevated temperatures [4]. More recently, a greater amount of attention is being given to PEME due to its ability for higher amounts of hydrogen production [5,6]. PEME is efficient and flexible and is a widely used technology that produces “green-hydrogen” from renewable energy sources. PEME is practical and offers several advantages over other methods of electrolysis, such as requiring smaller mass volume characteristics, having higher current densities, a higher degree of gas purity and better safety levels [7]. A basic schematic of a PEME is shown in Fig. 1a. Fig. 1b shows the principle of operation of a single PEME cell.

The PEME cell consists primarily of a PEM as an electrolytic conductor. The anode and cathode are fixed together and are known as the membrane electrode assembly (MEA). In the PEME, water molecules and ionic particles are transferred across the membrane from the anode to the cathode [8,9], where it is decomposed into oxygen, protons and electrons. In the reaction process, electrical energy is supplied to the system and transformed into chemical energy. The electrons exit the cell through an external circuit. The electrons and protons recombine at the cathode to release hydrogen gas.

The chemical reactions at the anode and the cathode are shown below.

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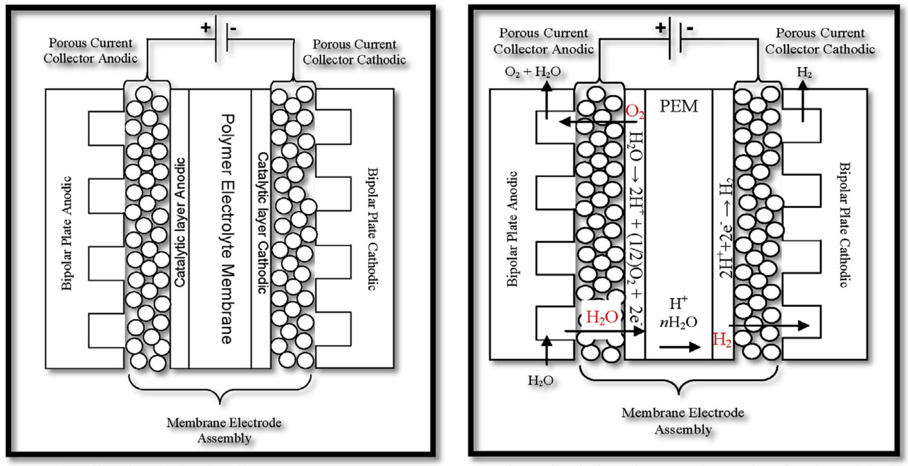

a. Single PEME cell b. Principle of operation of a single PEME

Fig. 1. Schematic diagram of PEME.

$$\text{Anode}: \ H_2O_{(l)} \rightarrow \frac{1}{2}O_{2(g)} + 2H^+{}_{(g)} + 2e^- \tag{1}$$

$$\text{Cathode}: \ 2H^+ + 2e^- \rightarrow H_{2(g)} \tag{2}$$

$$\text{Overall reaction}: \ H_2O_{(l)} \rightarrow H_{2(g)} + \frac{1}{2}O_{2(g)} \tag{3}$$

There is limited information in literature on the modeling of mass transport. More recently, researchers have studied different materials related to PEME to increase current densities and decrease cell voltage, thereby improving performance of the system as well as achieving low material cost. Therefore, there have been intensive studies focused on current collectors [10–12], bipolar plates [13–16] catalysts [17–26], membranes [27–34], and auxiliary power units [35] for the PEME. Fig. 2 shows the standard materials required for the PEME. It is worth mentioning that carbon materials such as carbon paper can only be used as current collectors at the anode for small scale test or short term experimental conditions, this is due to their undesirable corrosions that they undergo at anode [36]. The carbon materials are susceptible to corrosion due to strong acidic nature of the anode, high O_2 concentration and high voltage at the anode. Carmo et al. [36] concluded in their study that stainless steel grids or Ti grids could replace carbon materials, but these has lower performance when compared with sintered Ti particles. The modeling of PEME can be found in open literature but there has been no reported review on the PEME models compared to the PEMFC models [37–42]. In recent literature published by Ahmadi et al. [43,44], they studied hydrogen production via an ocean thermal energy conversion system with solar-enhanced PEME. Meanwhile Lamy et al. [45] observed the electrochemical decomposition of methanol

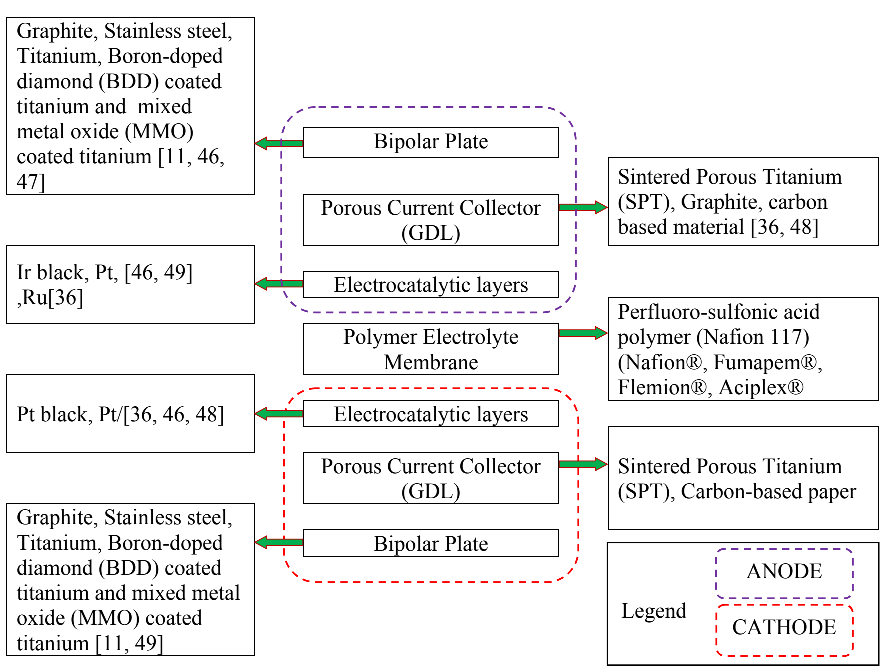

Fig. 2. PEME standard material.