INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 39 (2014) 17765–17778

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Review

A review of unitized regenerative fuel cell stack: Material, design and research achievements

Mohamed Gabbasa [a,b], Kamaruzzaman Sopian [a], Ahmad Fudholi [a], Nilofar Asim [a,*]

[a] Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[b] Department of Chemical and Process Engineering, Zawia Higher Institute of Polytechnics, Al-Zawia, Tripoli, Libya

ARTICLE INFO

Article history:
Received 20 May 2014
Received in revised form
21 August 2014
Accepted 23 August 2014
Available online 17 September 2014

Keywords:
Regenerative fuel cell
Polymer electrolyte membrane
Electrolyser
Stack
Performance
Platinum

ABSTRACT

The stack design of a unitized regenerative fuel cell (URFC) can modify the structure of cells that can be used as storage and energy regenerator aside from cells that use other sources such as solar or wind energy. A reversible unitized polymer electrolyte membrane fuel cell (PEMFC) contains a dual-functional single cell that is less expensive and has enhanced performance. The use of URFCs on hydrogen and oxygen is preferred because it is highly efficient, environmentally friendly, and uses power generators. The stack, then, must be made affordable or accessible. The expenses of URFC stack must be reduced by improving its design, materials, and performance. This study referred to recent studies on developing a method to cut the expenses of the URFC stack. The study also aims to determine its main constituents and to look further into its design by observing its performance and electrochemical behaviors. It also presents the issues that are currently encountered in this field.

Introduction

World development now calls for the minimal use of natural gas and pure oil as main sources of energy. The search is on for alternative or substitute sources as a response to climate change [1]. The concentration of the industrial countries in upcoming years will be on finding the cheaper and more accessible energy sources. The priorities in replacement of the conventional energy source are based on new source abundance, renewability and its impact on the environment [1,2]. Recent studies have focused on fuel cell technology because of its effectiveness and low effect on pollution [3]. These cells have been classified based on its electrolyte and its electrochemical element that directly converts stored chemical energy into electrical energy. Fuel cells are potential substitute energy sources that can reduce dependence on inner ignition engines. Attempts to make it commercially available can be successful by developing a hydrogen-based economy for reducing petroleum dependency, thereby reducing environmental damage [4]. The conventional battery that works by only hydrogen energy has been used in

* *Corresponding author*. Tel.: +60 3 89118576; fax: +60 3 89118574.
E-mail addresses: asimnilofar@gmail.com, nilofarasim@ukm.edu.my (N. Asim).
http://dx.doi.org/10.1016/j.ijhydene.2014.08.121

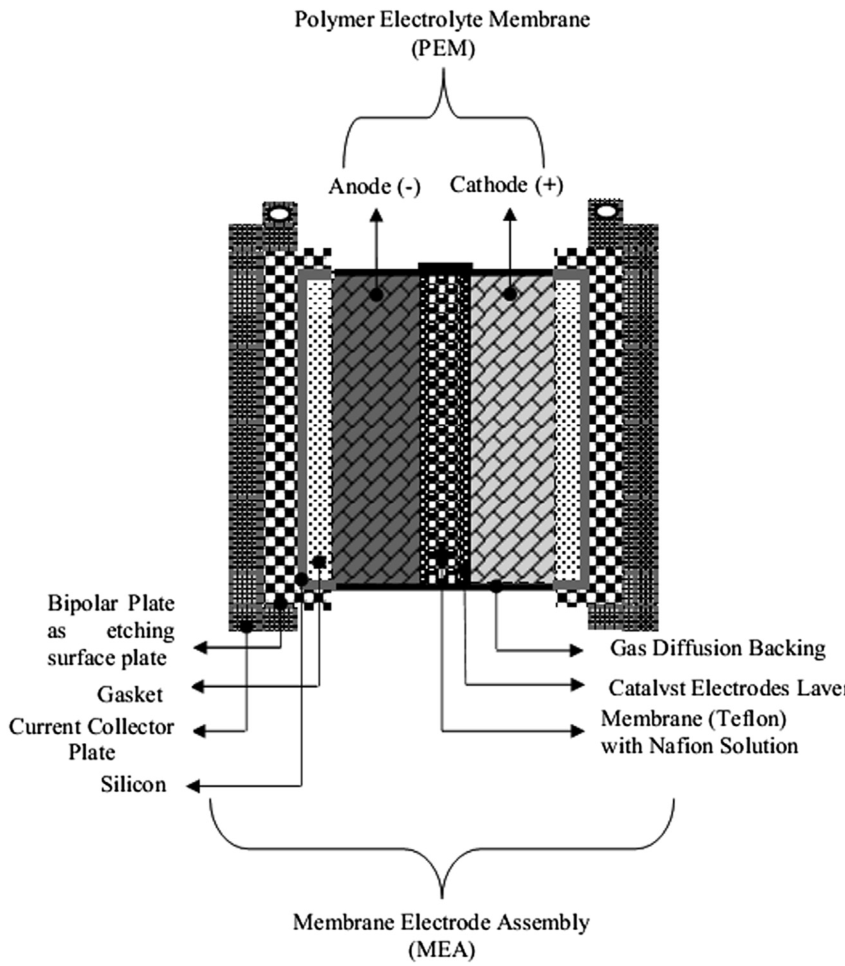

Fig. 1 – A schematic design of the MEA in URFC stack.

PEM fuel cell, and therefore, its low energy concentration is not capable of meeting the current demand. Moreover, the conventional batteries that have been used in this cell for these purposes have produced low energy density (<200 Wh kg^{-1}). This amount cannot meet the practical requires [5,6]. Regenerative-type fuel cells are a good alternative because they can function both as H_2/O_2 fuel cells. They can also electrolyse water with only an operation unit. Thus, the concentration of the feasible energy of URFC is capable of generating 400 Wh kg^{-1}–800 Wh kg^{-1} [6,7]. URFC is a reversible electrochemical tool that can function as H_2/O_2 fuel cells to generate electricity and heat, which is the so-called fuel cell mode (FC), and can electrolyse water to produce hydrogen and oxygen, which is the so-called water electrolysis mode (WE) [8,9]. Primary efforts to use URFCs in the proton exchange membrane technology have been done at the end of the 1960s. At that time, its mechanism and methods resulted in low electrochemical performance because of problems involving the membrane and electrocatalysts [10,11]. The General Electric Company (GEC) found more encouraging outcomes in the 1970s [12]. At the outset of the 1990s, researchers of the Lawrence Livermore National Laboratory (LLNL) developed a typical URFC stack that had a particular kind of power concentration of 500 Wh kg^{-1} [12,13].

Over the past few decades, all-inclusive fundamental experimental actualizations of single cell PEM-URFC performance have been conducted, but stack inquiry did not get much attention [13]. At first, URFC cell research concentrated on its material and the transport behavior phenomena, which include membrane electrode assembly (MEA) materials, bipolar plate design, MEA durability and degradation, and water and heat thermal management, as shown in Fig. 1. URFC stack level research has been primarily focused its performance and durability and aimed to characterize stack manner [14]. Technological developments should use the matching concept of the so-called "hydrogen and oxygen electrodes," such as H_2 produced in WE or consumed FC modes in the same cell cubicle, as well as O_2 produced in both WE or consumed FC modes in the other cell cubicle. This process requires the development of "reversible bifunctional electrodes," a task not commonly performed especially on oxygen electrodes when the H_2O/O_2 redox system is significantly irreversible at a temperature range of 80 °C–100 °C in the PEM technology. This process has advantages such as simpler management of gases, but it also has its disadvantages [15]. The problems involved in this process include material stability, corrosion of carbon-based materials (carbon used as catalyst carrier, gas diffusion layer, and bipolar plate) at the anode during water electrolysis. Thus, performance is significantly reduced [15,16].