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Comparative of heat transfer performance between a parallel serpentine-baffle flow field plate and a parallel flow field plate design in a direct ethanol proton exchange membrane fuel cell

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Abstract.

The dependence on fossil fuels as an energy source causes serious environmental problems. Direct ethanol proton exchange membrane fuel cells (DE-PEMFCs) that directly convert the chemical energy stored in the etanol alcohol into electricity makes it promising as an environment-friendly power source for portable and mobile applications. Increasing the reagent operating temperature increases the electrochemical kinetics at the anode, increasing the cell power. However in a DE-PEMFC, the flow field plate directly interferes at the heat flow. As a result, the aim of this research were project a new parallel serpentine flow field plate with interdigitated characteristics, a parallel serpentine-baffle flow field plate (PSBFFP) and comparing with a PSFFP with respect to heat transfer performance in a DE-PEMFC anode side. The results show that the discontinue channels presents in the PSBFFP improve the heat transfer between plate and reagent, improving the reaction rate and consequently the fuel cell performance.

Key words

Fuel cells, ethanol, parallel serpentine-baffle flow field plate, heat transfer.

1. Introduction

Fuel cells are considered to be the green power sources for the 21st century, and may make the "hydrogen economy" a reality. [1]

The dependence on fossil fuels as an energy source causes serious environmental problems. Additionally, the depletion of these resources and the ever-increasing prices provide further motivation for the search for ways of generating power more efficiently with less impact on the environment. [2]

Direct alcohol proton Exchange membrane fuel cells (DA-PEMFCs) that directly convert the chemical energy stored in the alcohol into electricity makes it promising as an environment-friendly power source for portable and mobile applications [3, 4].
Among various alcohol fuels, ethanol is less toxic and can be massively produced from agricultural products or biomass, in addition to the advantage of high-specific energy. [5]

One of two major problems for DE-PEMFCs is the sluggish anode kinetics. [2]

Increasing the operating temperature increases the electrochemical kinetics at the anode, increasing the cell voltage. On the other hand, the increase in the operating temperature enhances the mass and charge transports, which consequently reduces the ohmic loss and concentration loss. Therefore, the cell performance improves as the temperature is increased over the whole current density region, including the activation, ohmic and concentration-controlled regions.[5]

Fuel cell performance slightly increases with increasing reagents temperature, being this trend perceptible in the simulated polarization curves and confirmed by the protonic conductivity predictions. The protonic conductivity values are higher for higher temperature values [6]. In a DE-PEMFC, the flow field plate have a range of functions, including heat flow.[7]

Currently parallel serpentine flow field plate designs have emerged as the industry standard because of their high performance. They are often used as the reference design when evaluating new designs [8, 9, 10, 11, 12]. At the same time, the interdigitated flow field design is gaining attention of the scientific community because the basic idea of this flow field design is to force the total mass flow through the land area to improve the local cell performance [13, 14].

2. Objectives

The aim of this research were project a new parallel serpentine flow field plate with interdigitated characteristics, a parallel serpentine-baffle flow field plate (PSBFFP) and comparing with a PSFFP with respect to heat transfer performance in a DE-PEMFC anode side.

3. Methodology

3.1. Creation of the PSBFFP

The Figure 1(a) shows a PSFFP illustration and the Figure 1(b) an illustration of the IFFP. The new PSBFFP should collect the PSFFP parallel serpentines and the IFFP discontinuous channels in a unique flow field plate.

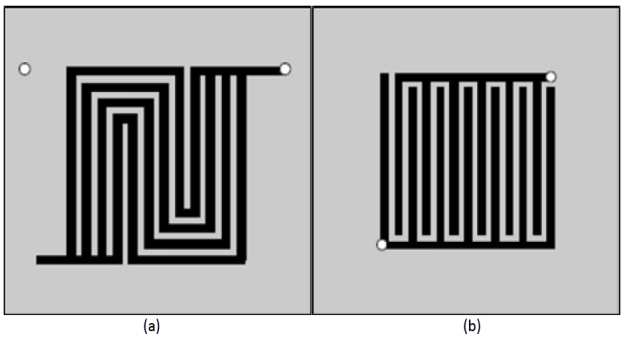

Fig. 1. Illustration of (a) a PSFFP and (b) a IFFP

To create the new flow field design the solution was disconnect two of three PSFFP channels to the output, becoming these channels partially discontinuous. Figure 2 shows the new PSBFFP illustrated by applying SOLIDWORKS software.

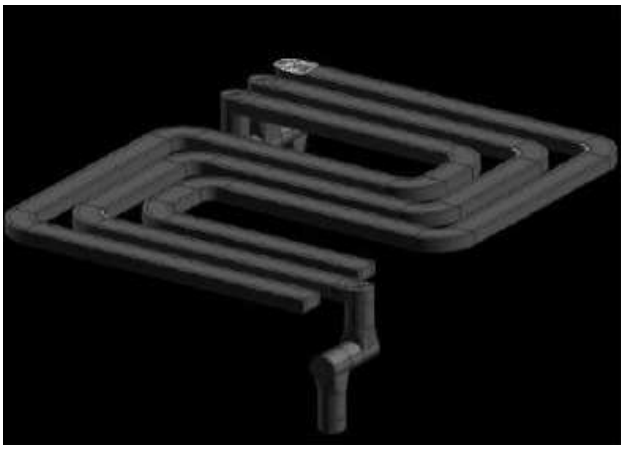
Fig. 2. The new PSBFFP illustrated by applying SOLIDWORKS software

3.2. Test set up

The flow field plates were made up of graphite by machining commercial solid graphite used in specially-manufactured refractory pieces.

The solid graphite was produced by Graphitas Com. Rep. Ltda (BR), from raw material provided by Poco Graphite Co. (USA), with a very thin lattice structure and consistent grain quality through an isostatic process. Two flow field plates with parallel serpentine-baffle flow field (PSBFFP) were produced and two with the parallel serpentine flow field plates (PSFFP). Images of these plates are shown in Figures 3 and 4 respectively.

Miniature plate pairs were produced with dimensions of 46.8mm x 46.8mm x 10mm in a chiral way with two holes for connecting a thermocouple and a dynamic load device. Both plate types were made with 3 flow channels with the same cross sectional area, 2 mm wide and 1 mm height, and 2 ribs 1.37mm wide. The flow field channel area was 29mm x 29mm.

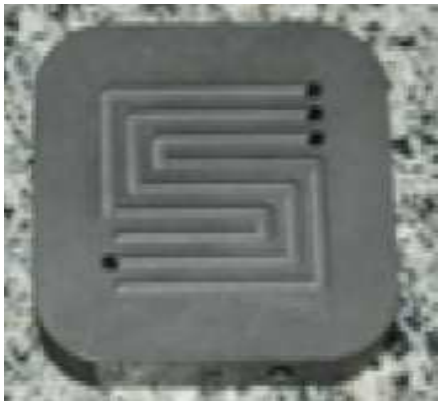
Fig. 3. PSBFFP photo.


Fig. 4. PSFFP photo.

The PEMFC prototype single cell consisted of the MEA sandwiched between two graphite flow field plates in an external stainless structure which allowed the compression of the fuel cell components. Teflon plates were used as thermal insulators to prevent heat exchange between the plates and the environment. Figure 5 shows a view of the fuel cell test station built and used in the experiments. The reactant inlet and outlet in the cell were fitted perfectly onto the flow field plates which support the MEA. Insulating gaskets of silicone elastomeric were used to seal the plates and the PEMFC prototype was tightened by screws at a torque of 3Nm.

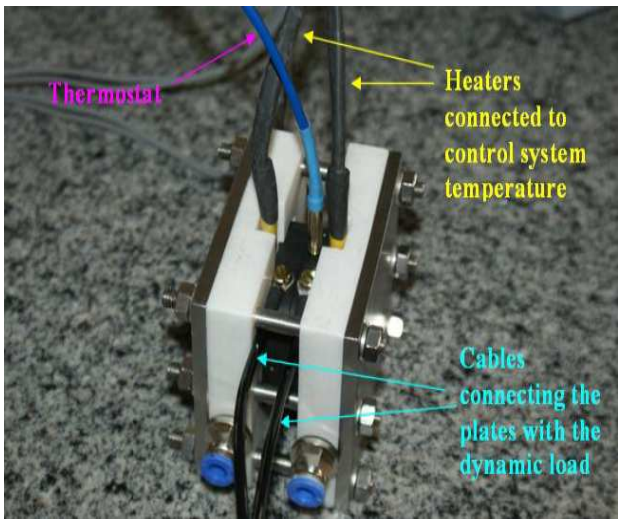

Fig. 5. DE-PEMFC prototype of UFRGS University

For the first test the DE-PEMFC was equipped with a PSFFP at the anode and at the second test was equipped with a PSBFFP in the same electrode. As shown in Figure 2 the PSBFFP has 3 input and only 1 output channels and as shown in Figure 3 the PSFFP has 3 input and 3 output channels.

At both tests the plates had the initial temperature controlled in 13ºC. During 6 minutes 1 L/min of water flow, controlled at 80ºC, was inserted at the anode input plate. After the 6 minutes each anode flow field plate temperature was measured by a thermal sensor (model FLUKE Ti20). Figure 6 shows the DE-PEMFC test unit flow diagram.

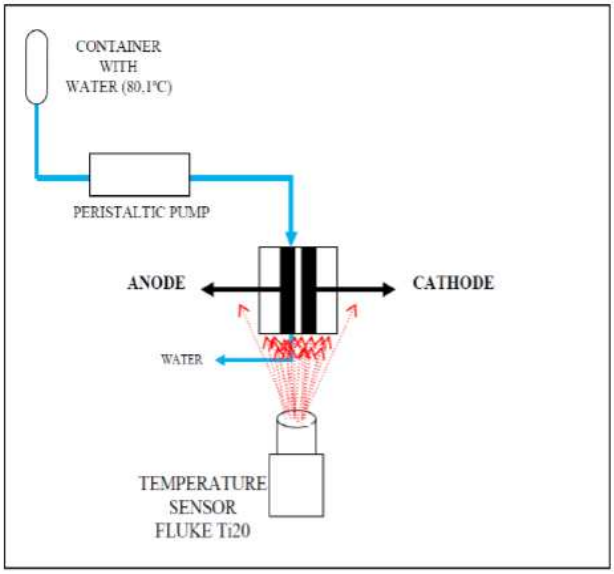

Fig. 6. DE-PEMFC test unit flow diagram with a temperature sensor FLUKE Ti-20

4. Results and Discussion

As a result, when the DE-PEMFC was equipped with PSFFP, after 6 minutes, the flow field plate reached 28.5ºC. On the other hand, when the DE-PEMFC was equipped with PSBFFP, after 6 minutes, the flow field plate reached 33ºC. Figure 7 shows an infrared photo about (a) the initial situation and (b) the situation after 6 minutes when the DE-PEMFC was equipped with PSFFP. Figure 8 shows an infrared photo about (a) the initial situation and (b) the situation after 6 minutes when the DE-PEMFC was equipped with PSBFFP.

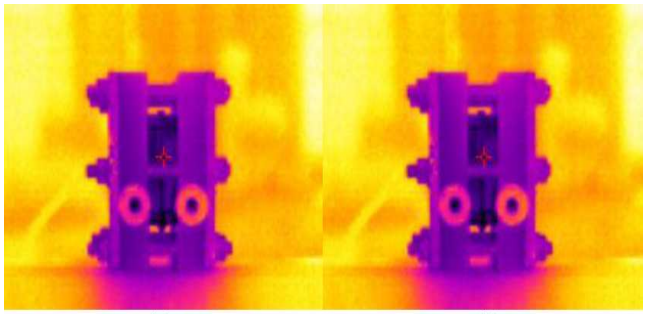

Fig. 7. Infrared photo of DE-PEMFC equipped with PSFFP (a) at initial situation and (b) after 6 minutes

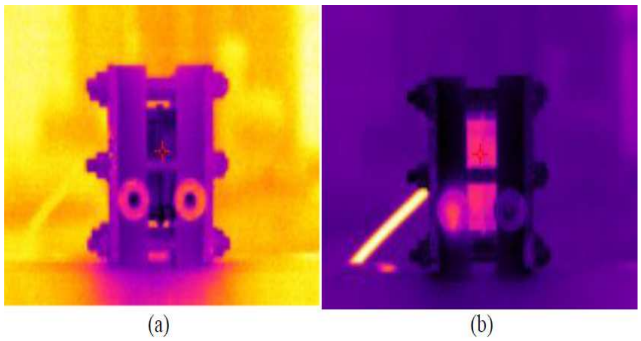

Fig. 8. Infrared photo of DE-PEMFC equipped with PSBFFP (a) at initial situation and (b) after 6 minutes

During a fuel cell operation the flow field plates are the heat source and the heat transfer quality of these plates is very important. Increasing the fluid (ethanol and oxygen) temperature increases the electrochemical kinetics of both electrodes, accordingly, increasing the cell voltage. On the other hand, the increase in the fluid temperature enhances the mass and charge transports, which consequently reduces the ohmic loss and concentration loss. Therefore, the cell performance improves as the fluids temperature is increased over the whole current density region, including the activation, ohmic and concentration-controlled regions [15].

When operating the PEM fuel cell, both of heat and water management in the stack continuously change as the load current varies. Elevated temperature increases the mobility of water vapor, which reduces the ohmic over-potential in the membrane and eases removal of water produced [16].

4. Conclusion

As a result, the discontinuous channels presents in the PSBFFP improve the heat transfer between plate and reagent, improving the reaction rate and consequently the fuel cell performance.

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