CHAPTER 4
EXPERIMENTAL STUDY OF BIPOLAR PLATES FOR (PEMFC)

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4.1 INTRODUCTION

The flow channel design of bipolar plates directly affect on the proton exchange membrane fuel cell (PEMFC).Commercial computational fluid dynamic (CFD) software COMSOL has been used to study and enhance different designs of the bipolar plates as shown in pervious chapters. To select the optimum design has been implemented as validated by experimental results. A good agreement between numerical results and compared by experimental results has been obtained.

The results obtained from numerical model was validated by experimental study using fuel cell test station, different designs of bipolar plates for PEM fuel cell have been used, the measurements of current density, power and power density were measured.

4.2 EXPERIMENTAL SET UP

A single PEM fuel cell was used for all experiments connected to a fuel cell test station as shown in Figure (4.1). The membrane electrode assembly (MEA) consists of a Nafion membrane in combination with platinum loadings of 0.4 mg/cm2 per electrode. The gas diffusion layers are made of carbon paper. The MEA positioned between two graphite plates is pressed between two gold-plated copper plates. The fuel cell test station is manufactured by scribner , its model is 850e and it can control the fuel cell temperature, humidification temperatures and backpressures on both the anode and cathode sides through a computer. In the test station, reactant gases are humidified by passing through external water tanks. Regulating the water temperature controls the humidification of the reactant gases. Fuel cell temperatures and humidification temperatures are controlled. Backpressures are controlled by backpressure regulators. This station also includes a computer-based control and data acquisition system. The computer system is connected to mass flow controllers, which are located before the humidifiers. The mass flow rates are set and read through the software. The fuel cell polarization curves are obtained from this program as well by controlling the Electronic Load, which measures the voltage verses current response of the fuel cell.
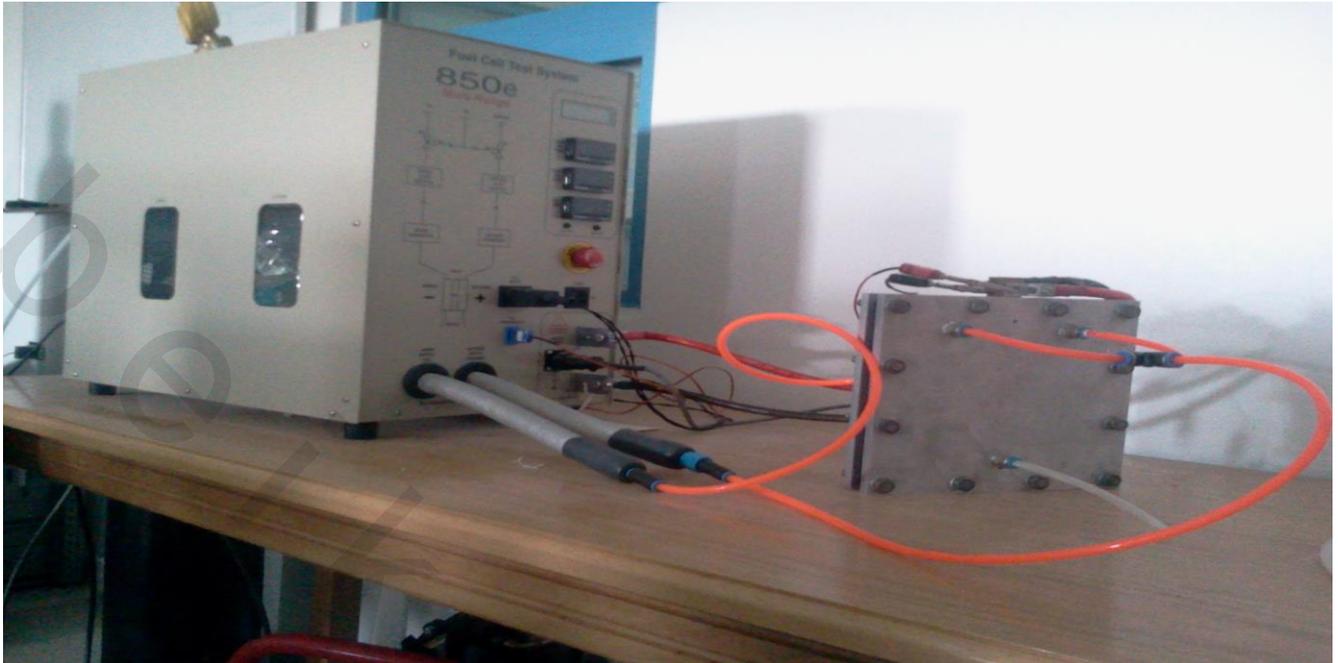
Figure 4.1 Fuel cell test station and setup.
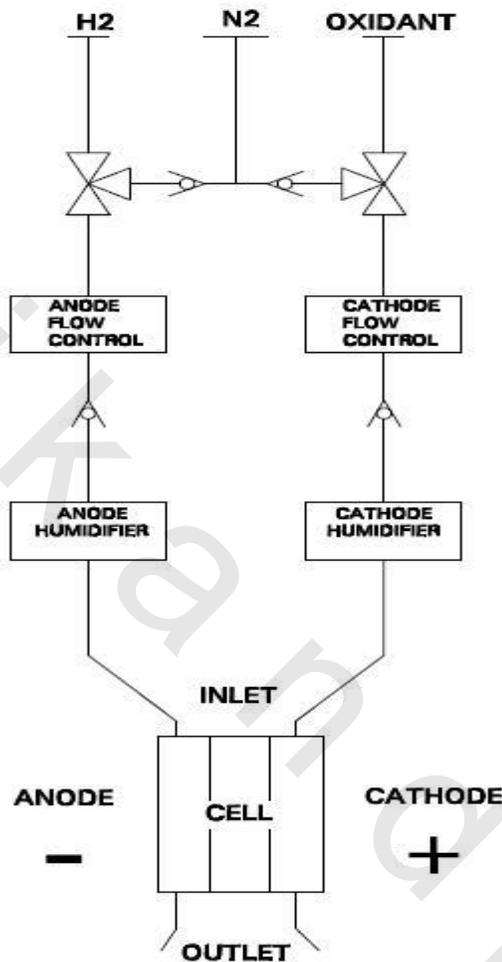
4.3 FLOW CHART EXPERIMENTAL

Figure 4.2 Fuel cell test station flow chart.

The procedure for each experiment is as follows:

1) Power on the Fuel Cell Test Station (FCTS) and open the valves of the gas cylinders of hydrogen, nitrogen and air.

2) Before starting experiments, purge the anode side with nitrogen to ensure no oxygen is present.

3) Set the experimental parameters of mass flow rate, fuel cell temperature, humidification temperature and backpressure.

4) Set the maximum voltage, minimum voltage and voltage increment step of the fuel cell polarization data in the test software interface.

5) Set the delay between every two voltage verses current data points in the test software interface.

6) Start the computer program to automatically control experiments and collect data.
7) Test each design of bipolar plate and record the results.
8) Compare the results of different design of bipolar plates.
9) Obtain the optimum design has best performance.

4.4 MODEL 850E HARDWARE SPECIFICATIONS

Electronic Load:

Maximum Load Current:	50 A (5/25/50A model)
	100 A (10/50/100A model)
Maximum Load Power:	100 Watts
Minimum Load Resistance:	< 2.0 mw at Maximum Load Current
Current Resolution:	1 mA or 10 mA depending on range
Current Accuracy @ 25°C:	0.3% of full scale current rating for range selected
Minimum Load Resistance:	< 2 mw (100mV @ 50A at load terminals) for 100 A or 50 A model

Voltage Measurement and Data Acquisition:

Maximum Whole Cell Voltage:	20 V
Maximum Reference Electrode Voltage:	9.999 V
Sense Lead Input Resistance:	> 35 kw
Voltage Resolution:	1 mV
Voltage Accuracy:	+/-3 mV +/-0.3% of reading
Voltage and Current Data Update Rate:	100 H

Reactant Gas Control System:

All 316 SS construction of humidifiers, flow path, valves and mass flow controllers, with Swagelok® fittings and heated reactant delivery lines.

Mass Flow Control:	Standard Anode 1000 SCCM and cathode 2000 SCCM Software controlled mass flow controllers. Automatically controlled N2 purge valves on anode and cathode
Alarm Inputs:	Gas supply pressures (3), humidifier water levels (2) and external (1)
Backpressure Control:	Optional, 0-30 PSIG, requires 850BP accessory.

Temperature Controllers:

Quantity:	Three; cell fixture; anode and cathode humidifiers
Set and Report Accuracy:	+0.25% of span, +1 least significant digit
Sensor Type:	Thermocouple, Type T for cell (K optional)

Humidifiers:

Type:	Dual bottle-type, all 316L SS, 270 watt heater per bottle (360W for >2SLM units) Automatic water filling optional

Temperature Range:	Ambient to 95 degrees C.
Environment:	
Operating Temperature:	0- 40 degrees C
Source:	120V 50/60 Hz 8A or 10A max
	(220V Option Available)
Enclosure Type:	Single bench-top enclosure
Size:	17" 11 x 11" W x 19" D (+ 11" for heated gas lines) 44 x 28 x 49 (+ 28cm); 50 lbs.
Safety Features:	Automatic shutdown and N_2 purge with under voltage, over-current, and over-temperature, loss of supply pressures, low water, communications failure or external alarm. Manual Emergency Stop switch included for manual shutdown by operator.
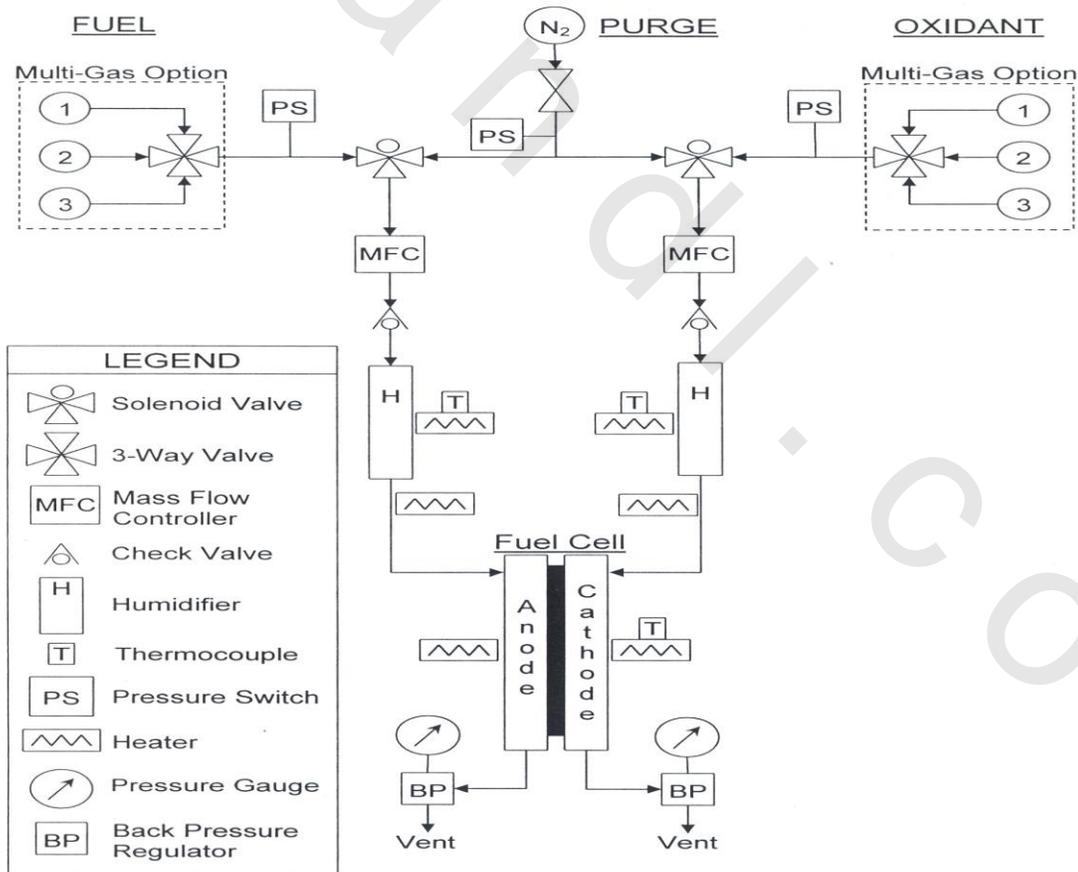
Figure 4.3 Fuel cell test station 850 e flow diagram.

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4.5 EXPERIMENTAL RESULTS

Figure 4.4 shows serpentine bipolar plate with 54 channels and 53 ribs, channel width is 1 mm and depth is 1 mm, plate width 150 mm and length 150 mm with effective area 5898 mm^2. On other hand, Figure 4.5 shows serpentine bipolar plate with 51channels and 50 ribs, channel width is 1 mm and depth is 1 mm, plate width 150 mm and length 150 mm with effective area 5424 mm^2.
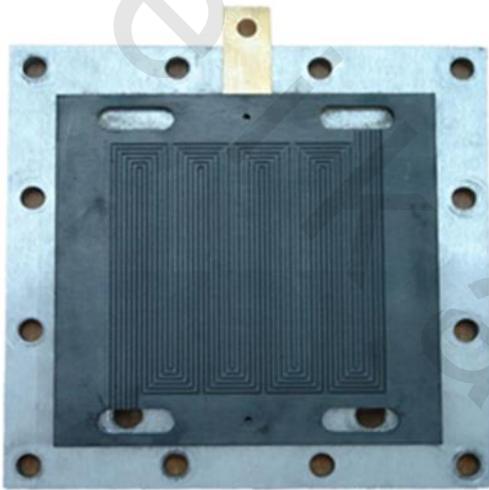

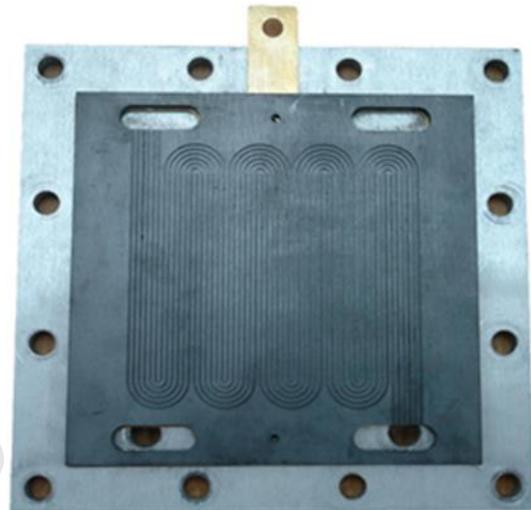**Figure 4.4 Photo for design one six serpentine flow channels with square bend**

Figure 4.5 Photo for design two six serpentine flow channels with curvilinear bend

Figure 4.6 shows experimental polarization curves for design one and design two, for air flow rate 42 L/min and hydrogen flow rate 21 L/min. It can be seen in the figure that both designs on open circuit cell voltage have the same trend. The differences observed in the polarization curves could have been causes by differences in the flow velocity inside the channels, the distribution of fuel in the diffusion layer, and for a pressure drop of the fluid inside the channels. As is shown the three different regions are found in PEMFC. Both designs have the same cell voltages up to 7.5 mA/cm^2, After 7.5 mA/cm^2 design two showed improvement of cell voltage than design one.
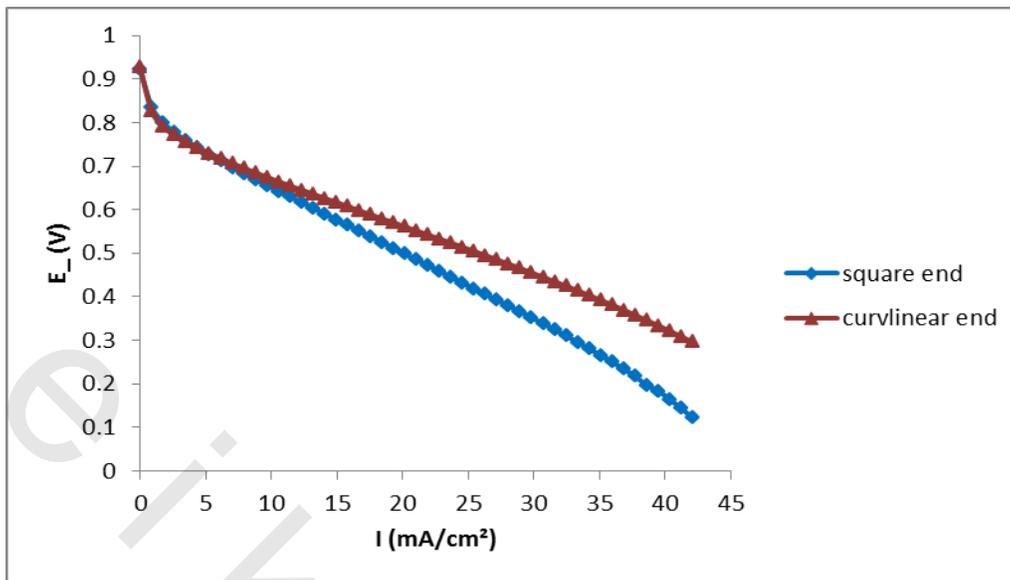
Figure 4.6 Experimental polarization curves for bipolar plate design one and bipolar plate design two verses cell current density.

Figure (4.7) Illustrates experimental power density curves for design one and design two, for air flow rate 42 lit/min and hydrogen flow rate 21 lit/min .It can be seen in the figure that both designs using open circuit cell voltage have the same trend. The differences observed in the power density curves could have been caused by differences in the flow velocity inside the channels, the distribution of fuel in the diffusion layer, and for a pressure drop of the fluid inside the channels. As is shown the three different regions are found in PEMFC. Both designs have the same power density up to 15 mA/cm^2, after 15 mA/cm^2 design two showed improvement of power density than design one.
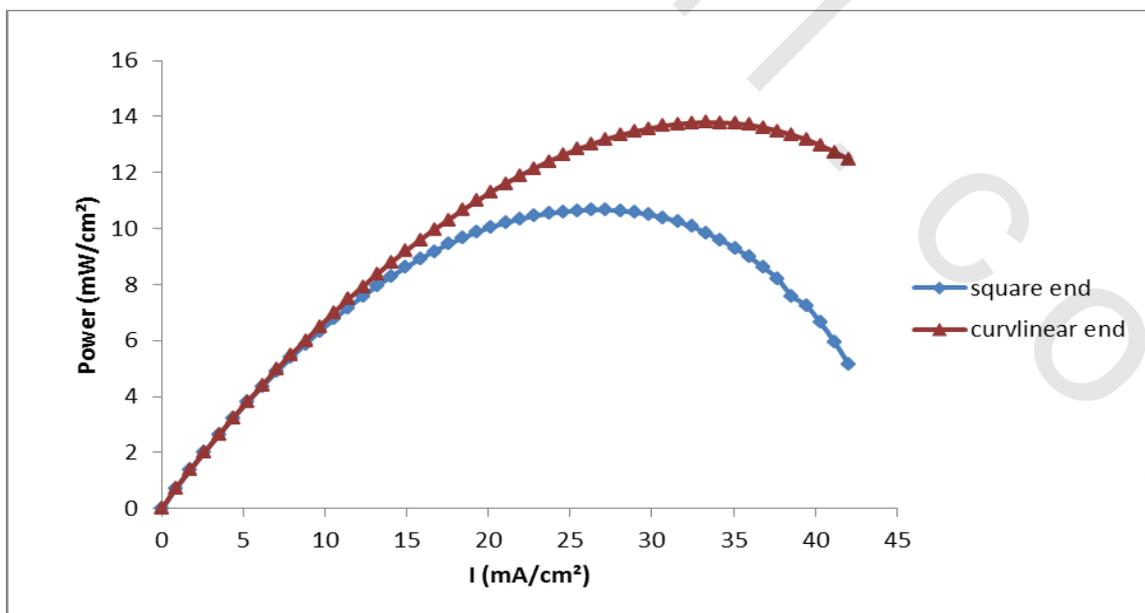

Figure 4.7 Experimental power density curves for bipolar plate design one and bipolar plate design two verses cell current density.

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Figure 4.8 Demonstrates experimental cell power curves for design one and design two, for air flow rate 42 lit/min and hydrogen flow rate 21 lit/min. as can be seen in the figure the both two designs on open circuit cell voltages have same trend. The differences observed in the cell power curves could have been causes by differences in the flow velocity inside the channels, the distribution of fuel in the diffusion layer, and for a pressure drop of the fluid inside the channels. As is shown the three different regions are found in PEMFC. Both designs have the same value of cell power up to 15 mA/cm^2, After 15 mA/cm^2 design two showed improvement of cell power than design one.
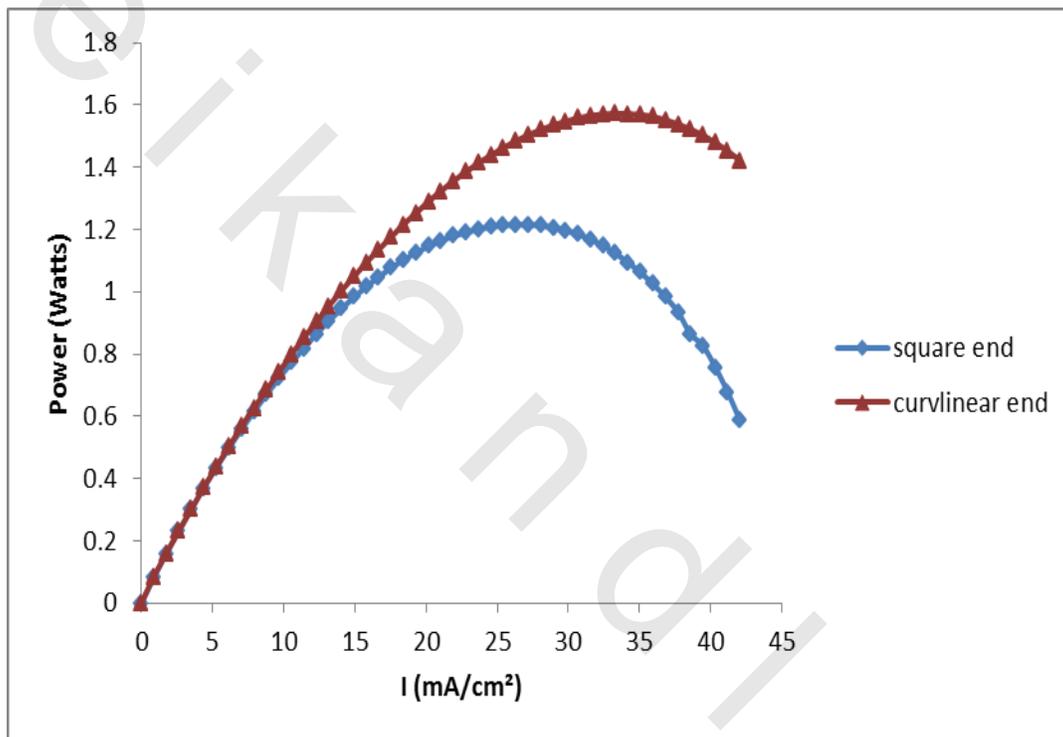

Figure 4.8 Experimental cell power curves for bipolar plate design one and bipolar plate design two verses cell current density.

4.6 BACK PRESSURE EFFECT

Different back pressures values have been applied for both side's air (cathode side) and H$_2$ (anode side) and their values were 20 KPa, 40 KPa, 60 KPa, 80 KPa, 100 Kpa using back pressure unit showed in figure 4.9 which applied on fuel cell in figure 4.10 .

Figure 4.9 Back pressure unit.

4.6.1 Fuel cell description

4.6.1.1 Features:

- Anodized aluminum end plates standard.
- Configured for 110 V or 220 V operations.
- Operating temperature up to 200 °C.

4.6.1.2 Components:

- POCO graphite flow fields (2) with precision machined, serpentine flow-pattern
- Gold-plated copper current collectors (2)
- Anodized aluminum end plates (2) with reactant input/output ports, cartridge heaters and thermocouple well
- Templates for preparation of gaskets
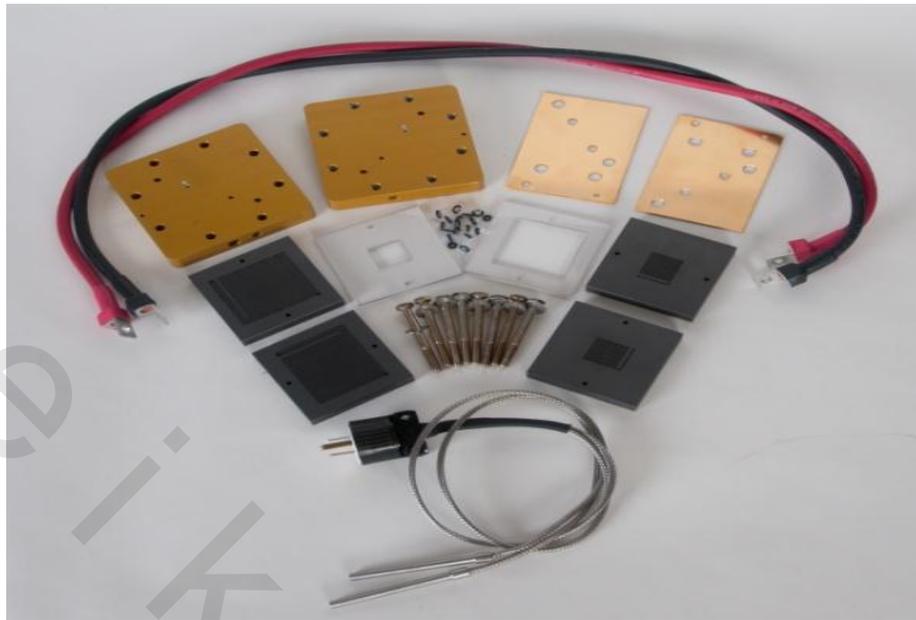- Additional hardware such as bolts, washers, fittings.

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Figure 4.10 Fuel cell components.

4.6.2 Results

As shown in figure 4.11 and 4.12 power density and cell voltage increase with back pressure increase. So, the performance of the fuel cell increases with an increase in back pressure in the flow channels. This is due to an increase in residence time of hydrogen in the channel. As a result there is an increase in the diffusion rate of hydrogen across the GDL.
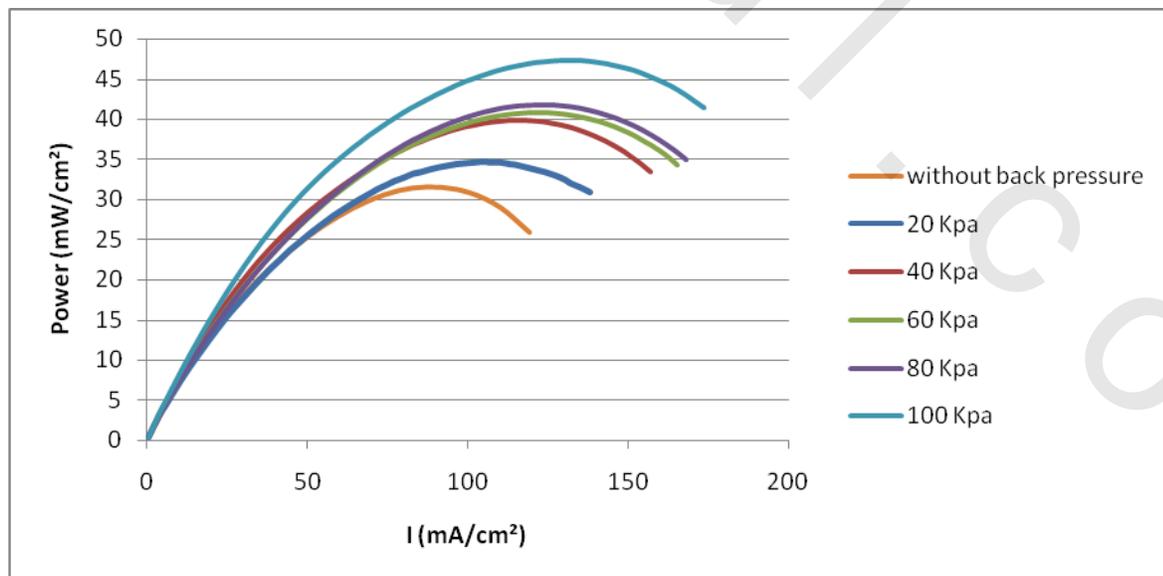

Figure 4.11 Relations between current density and power density at different back pressures.
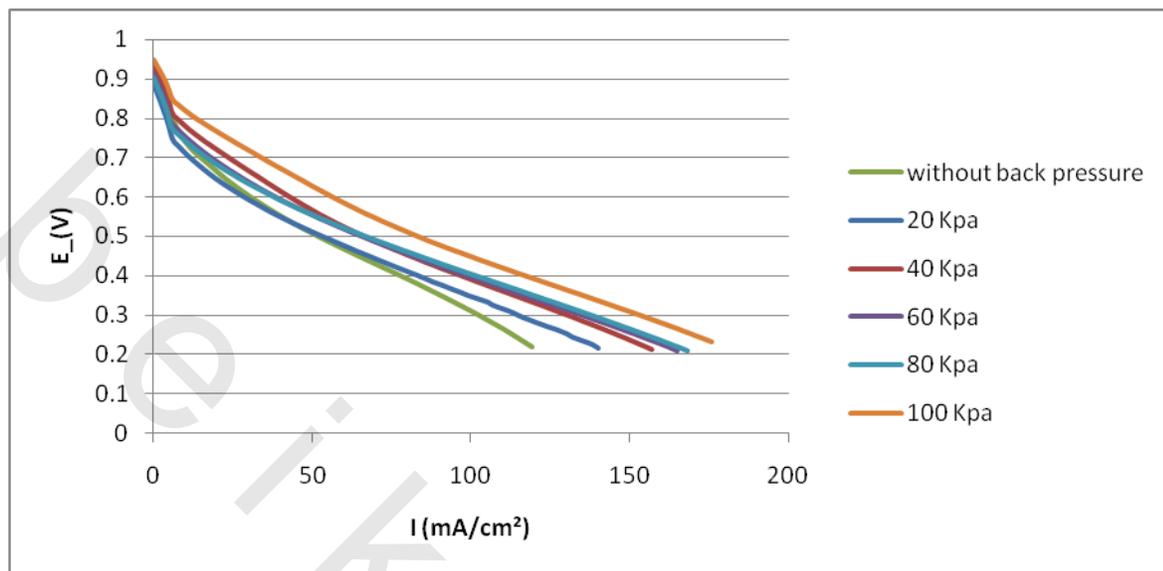
Figure 4.12 Relations between current density and cell voltage at different back pressures.