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An experimental investigation of proton exchange membrane (PEM) fuel cell at different operating conditions

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ABSTRACT

The performance of a proton exchange membrane (PEM) fuel cell is greatly affected by the operating parameters. Appropriate operating parameters are necessary for PEM fuel cells to maintain stable performance. The results indicate that the cell performance can be enhanced by increasing operating temperature. The anode humidification has more significant influences on the cell performance than the cathode humidification, and the best performance occurs at moderate air relative humidity while the hydrogen is fully humidified. In addition, the fuel and oxidant flow rate proves to be influencing the cell performance. Based on these conclusions, several suggestions for engineering practice are also provided.

Introduction

A fuel cell is a device that converts a fuel stream directly into electrical power. First significant applications was in the U.S space program starting in 1960s, for space applications fuel cell technology offered electricity generation and water production using hydrogen and oxygen gas. In the mean timefuel cell for stationary power generation was also being developed.Fuel cell technology is attractive for vehicle propulsion, offering low emission and a level of efficiency competitive with the best of reciprocating engine technology. There are several fuel cell technologies, all of which use a different electrolyte.

The technology most likely to be used in vehicle applications is the proton exchange membrane fuel cell (PEMFC). PEMFC is one of the most promising candidates for future power generation in transportation, stationary and mobile applications. In small scale applications, the fuel cell should be small and high energy density [1], while battery technology has improved considerably in recent years, the functionality, operating speed and lifetime of many portable devices are still limited in how long they can operate as truly portable (i.e. unplugged) devices by the quantity of energy that can be stored within them, fuel cells however provide significant advantages over conventional battery systems [2]. Interest in using fuel cells to power portable equipment for commercial applications is relatively recent. This is perhaps partly due to the success of Li based batteries in powering laptop computers, mobile phones and the like. The requirement for high energy density, higher specific energy or longer operational time between recharges was generally well served by the LI-ion battery and nickel-based batteries especially those based on metal hybrids. Safety and environmental factors were key considerations in addition to the high energy density of these batteries [3].

The main advantages are

- the flexibility with respect to power and capacity achievable with different devices for energy conversation and energy storage,
- the long time and long service life,
- the good ecological balance,
- Very low self discharge.

Most fuel cell research targets stationary premium power and automotive applications and stacks capable of delivering approximately 1-200 kW. The large cells are typically mechanically compressed sandwiches of graphite composites electrodes and membrane assemblies. To create a miniature fuel cell for portable devices that delivers power in the range of 0.5-20W, one will not achieve an optimum design by simply scaling down the larger system. Rather, one must redesign each component of the fuel cell with an eye towards miniaturization [4].

Experimental Setup

The image of the experimental setup is shown in Fig.1. The fuel test station (850 e) used for the performance study was imported from Scribner Associates Inc. USA., The single cell fixture with active area of 5 cm^2 was used with the test station. Hydrogen was supplied to the anode side, and oxygen to the cathode side from respective compressed gas cylinders through the humidity chambers. Nitrogen gas is also connected to the test station to purge both the gas flow lines when fuel is not flowing. The gases are controlled by the respective inbuilt mass flow controllers in the test station.

Fig 1. Fuel cell test station

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Single Cell Description

Single cell consist of two electrodes separated by an electrolyte. Two electrodes are carbon paper with catalyst coated and electrolyte is a membrane sandwiched between the two electrodes, it is called as Membrane Electrode Assembly (MEA). MEA (fig 2) with an active area of 5 cm^2 was used for the experimental study. Anode side electrode was hydrophobised 20 % with PTFE and cathode side 30 % with PTFE [5, 6].

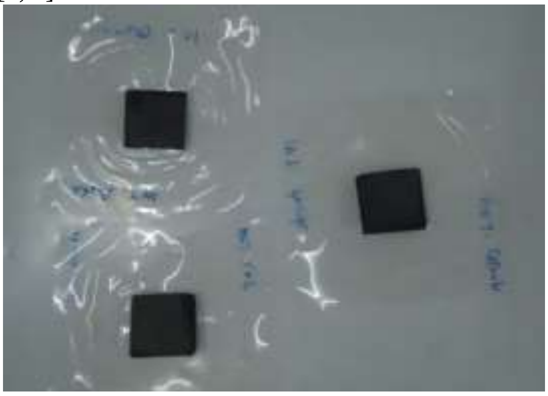

Fig 2.Membrane Electrode Assembly

40 % Pt/C with a loading of 1 mg/cm^2 was used on both anode and cathode catalyst layer. Fig 3 shows SEM image of catalyst showing the platinum on carbon powder

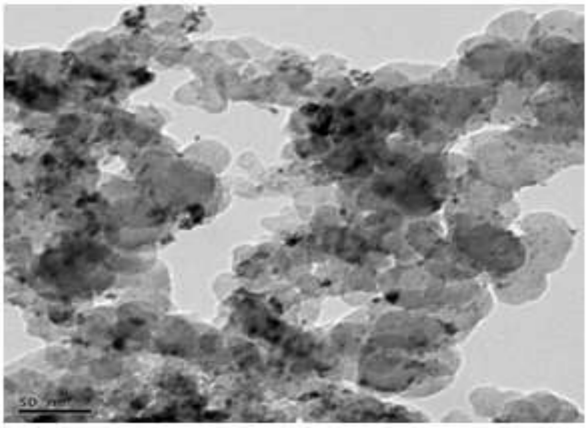

Fig 3.SEM image of catalyst showing the platinum on carbon powder

The electrolyte membrane used was Nafion 117 [7]. Fig.4 shows the exploded view of the single cell.

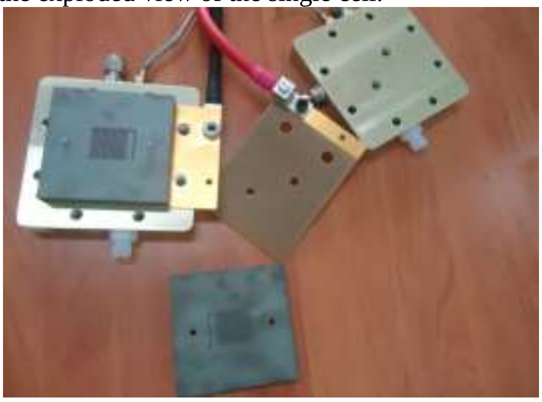

Fig.4 Exploded view of a single cell

Graphite flow field plates used for the single cell fixture. The thickness of the plate is 13 mm and the channels dimensions are 0.9 X 0.9 mm. The current collector plates used were copper plates with gold coating. The end plates were made of stainless steel.

Result and Discussions

Reactant flow rate

Effect of varying hydrogen flow rate:

The operating pressure is 5 kg/cm^2.the cell temperature is set as 60^0C and the reactants humidification temperatures are set to be 50^0C. The effect of PEM fuel cell performance with varying hydrogen flow rate is shown fig.5.The oxygen flow rate set as constant.

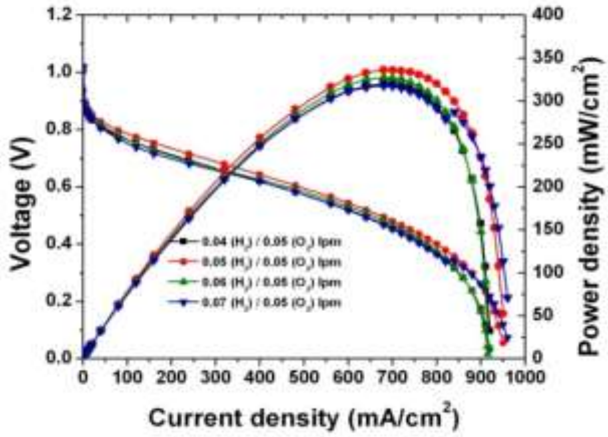

Fig. 5 Varying hydrogen flow rate

At 0.07 lpm hydrogen flow rate the water form due to back diffusion, humidified reactants and electro chemistry is flushed away with the outlet gases. Hence the limiting current density is higher for higher flow rate.

Effect of varying oxygen flow rate

The operating pressure is 5 kg/cm^2.the cell temperature is set as 60^0C and the reactants humidification temperatures are set to be 50^0C. The effect of PEM fuel cell performance with varying oxygen flow rate is shown fig 6.The hydrogen flow rate set as constant.

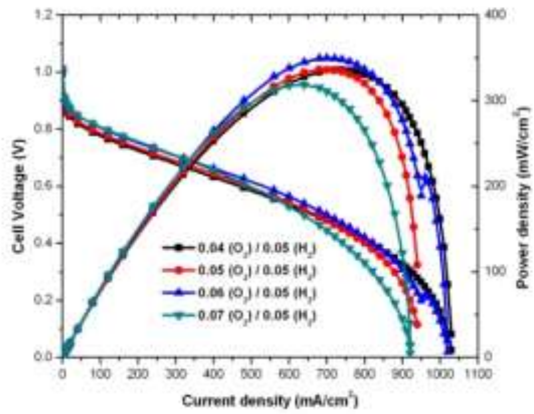

Fig.6. Varying oxygen flow rate

At 0.07 lpmoxygen flow rate the water form due to electro osmoticdrag, humidified reactants and electro chemistry is flushed away with the outlet gases .hence the limiting current density is higher for higher flow rate.

Effect of Humidification temperature

Effect of anode humidification temperature

The operating pressure is 5 kg/cm^2.the cell temperature is set as 60^0C and the flow rate of hydrogen and oxygen are 0.05 and 0.06 lpm. The effect of PEM fuel cell performance with varying anode humidification temperature is shown fig 7.The cathode humidification temperature set as constant. at higher hydrogen humidification temperature the limiting current density is higher. If the humidification temperature is higher, the membrane gets hydrated. So ionic conductivity increases and proton conductivity always increases. So cell performance increases in the 70°C humidification temperature. At 40°C hydrogen humidification temperature the limiting current density is low. Because water vapor content and proton conductivity low compared 70°C humidification temperature

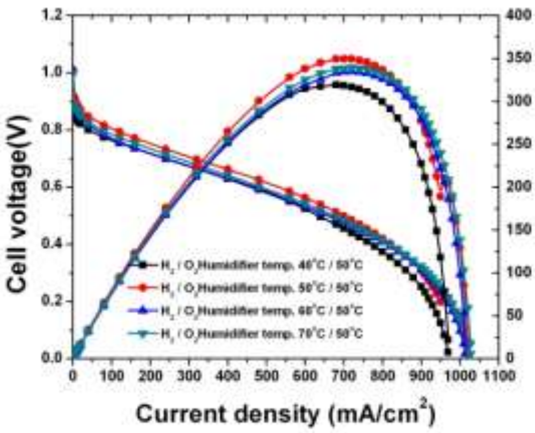

Fig.7 Varying hydrogen humidification temp.

Effect of cathode humidification temperature

The operating pressure is 5 kg/cm², the cell temperature is set as 60°C and the flow rate of hydrogen and oxygen are 0.05 and 0.06 lpm. The effect of PEM fuel cell performance with varying cathode humidification temperature is shown fig 8. The anode humidification temperature set as constant.

At higher oxygen humidification temperature the limiting current density is lower. If the humidification temperature is higher, the water flooding occurs. So cell performance decreases in the 70°C humidification temperature.

At 50°C oxygen humidification temperature the limiting current density is high, because water vapor content and proton conductivity high compared to 70°C humidification temperature

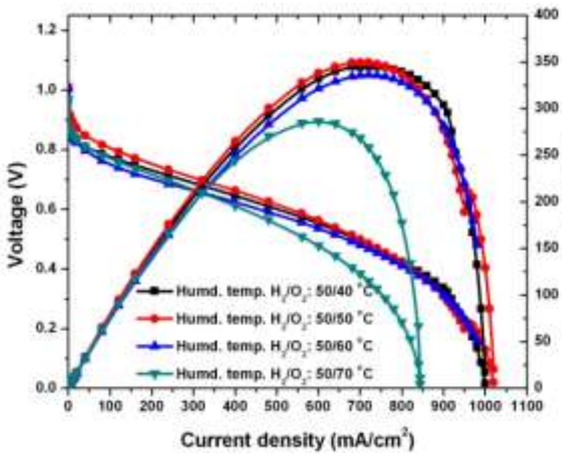

Fig 8. Varying oxygen humidification temp

Effect of Cell temperature

The flow rate of hydrogen and oxygen are 0.05 and 0.06 lpm. The operating pressure is 5 kg/cm² and the reactants humidification temperatures are set to be 50°C. The effect of PEM fuel cell performance with varying cell temperature on the PEM fuel cell performance is shown in fig 9.The cell temperatures varied 30°C, 45° C, 60°C and 80° C.

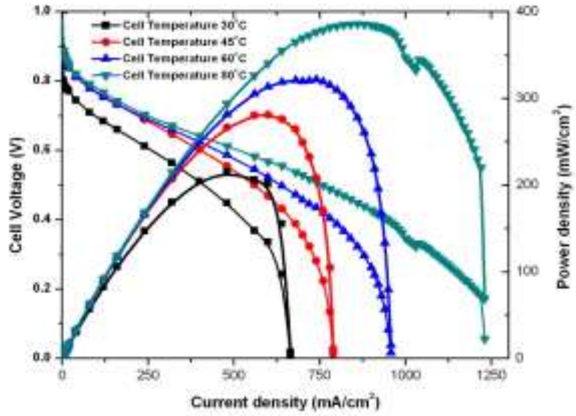

Fig.9 Varying Cell temperature

The fuel cell performance improves with increasing cell temperatures. In the 80° C the limiting current density is 1207.2mA cm². The 60° C the limiting current density is 951.5mA cm². The 45° C the limiting current density is 779.38mA cm².the 30° C the limiting current density is 636.29mA cm² .The measured peak power increases from 215.38 mW/cm² at30° C to 385.8Mw/cm² at 80° C .

The experiment is also tried by increasing the cell temperature to 90°C. This causes complete drying of water content inside the Nafion membrane and the membrane electrode assembly deteriorates. Hence reduced performance compared to 80°C (fig .10).

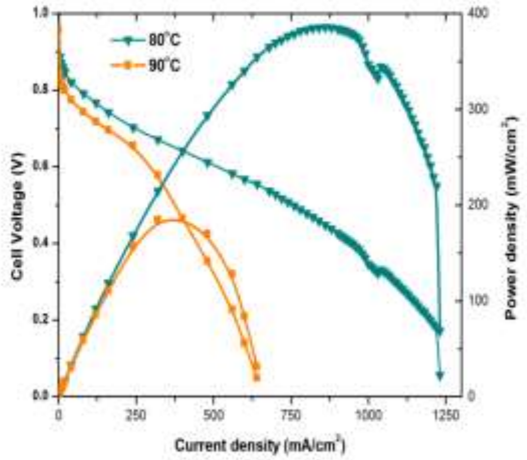

Fig 10 Performance at 80° and 90°C

Since the cell temperature is 80° C and reactants humidification temperature is maintained at 50°C the water vapor formed as the product of the electro chemical reaction leaves the cell with the reactants without condensing.

When the cell temperature is 30° C the water vapor formed as the product of the electro chemical reaction condenses inside the cell, also the water vapor coming with humidified reactants condenses inside the cell which leads to water flooding .water condensation over the active areas blocks the pores of the carbon paper and prevents the reactants from reaching the reaction sites. Similarly as cell temperature decreases the flooding in the cell increases with decrease in performance.

Conclusion

From the experiments conducted the performance of the PEM fuel cell is better with increased in cell temperature. The effect of varying hydrogen flow rate0.05 and 0.07 lpm is best compared other flow rates.

The effect of varying oxygen flow rate 0.06 and 0.07 lpm is best compared other flow rates. The effect of anode humidification temperature50^{o}Cand70^{o}C is better compared other humidification temperatures. The effect of cathode humidification temperature 50^{o}C is better compared other humidification temperatures .The cell temperature 60^{o}C and80^{o}C is better compared other cell temperatures.

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References

1) Terohottinen, mikkomikkola. peterlund "Evaluation of planer free-breathing polymer electrolyte membrane fuel cell design", J. Power Sources 129(2004) 68-72

2) Jeremy P.Meyers,HelenL.Maynard "Design consideration for miniaturized PEM fuel cell" J. Power Sources 109(2002) 76-88

3)C.K.Dyer"fuel cell for portable applications" J. Power Sources 106 (2002) 31-34

4) A.Heinzel, C.Hebling, M.Muller, M.Zedda, C.Muller "fuel cell for low power applications" J. Power Sources 105 (2002)250-255.

5) Ayse Bayrakceken, SerdarErkan, LemiTurker and InciEroglu, "Effects of membrane electrode assembly components on proton exchange membrane fuel cell performance", October 2007.

6) SasikarnEndoo, KejvaleePruksathorn, and Pornpote Piumsomboon, "Identification of key variables in membrane electrode preparation for PEM fuel cell by factorial design", October 2009.

7) Yong-Hun Cho, Hyun-Seo Park, Yoon-Hwan Cho, Dae-sik Jung, "Effect of platinum amount in carbon supported platinum catalyst on performance of polymer electrolyte membrane fuel cell, "Energy analysis of a PEM fuel cell at variable operating conditions ".