Study of effect of platinum loading and nano particles on the performance of PEM Fuel Cell

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Abstract

The PEM Fuel Cell is an electrochemical device which allows the direct & efficient conversion of chemical energy stored in fuel along with oxidant into electrical energy .The efficiency of PEMFC Depends upon various parameters such as H_2 humidification temp., H2 flow rate, platinum loading on membrane, stack temp. Etc. in this paper effect of diff. platinum loading on membrane and nanoparticle addition in the humidifier has been studied. The cell studied in this experimentation is single cell unit having 25cm^2 as an active area. Bipolar plates with serpentine flow channel, MEA with platinum loading of 0.5 mg Pt/cm^2 & 2.0 mg Pt/cm^2 .The experimental results are given in the form of polarisation curve and power density curve from the experimentation it is found that at platinum loading of 0.5 mg Pt/cm^2 ,h$_2$ humidification temp. of 55^0 C,H_2 flow rate 1.0 l pm ,stack temperature of 65^0C-70^0C,0.35 gm alumina nanoparticle addition ,the maximum voltage obtained is 0.934 V, current density of 3.6×10^{-8} A/cm^2 and voltage efficiency of 75.60% for the single cell unit.

INTRODUCTION

Proton Exchange Membrane (PEM) fuel cells are considered as strong competent in the quest for alternative energy sources. This is due to their compactness, low weight, high power density, clean, pollutant free operation and wide operating range. From the operational point of view, a relevant aspect is their low temperature of operation (typically 60–80 °C), which allows fast starting times. The PEMFC is the strongest among the other types of fuel cell due to it's technological maturity for commercialisation in the near future for transportation and stationary application.{1}A PEMFC stack consist of bipolar plates(BP),membrane electrode assembly (MEAs),gas diffusion layer (GDLs),current collector, end plates and sealants .These parts of the fuel cell stack govern it's cost and performance.{2} In a PEM Fuel Cell, a hydrogen-rich fuel is injected by the anode, and an oxidant (usually pure oxygen or air) is fed through the cathode. Both electrodes are separated by a solid electrolyte that allows ionic conduction and avoids electrons circulation. Catalytic oxidation of H2 and catalytic reduction of O2 take place in the negative and positive electrodes, respectively. The output of a PEM Fuel Cell is electric energy, with water and heat as then only by-products. {3} this is shown schematically in the following fig.

Fig 1.
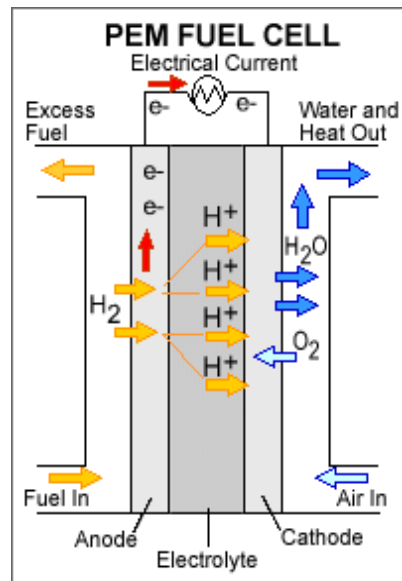
A typical schematic of a PEMFC is shown in fig.2 the cell is a sandwich of two graphite bipolar plates with micro flow channels and separated by MEA which consist of a membrane & two electrode with Pt. Catalyst .the GDL is porous to supply reactants to the electrodes in an unexposed areas of the micro flow channel. {4}
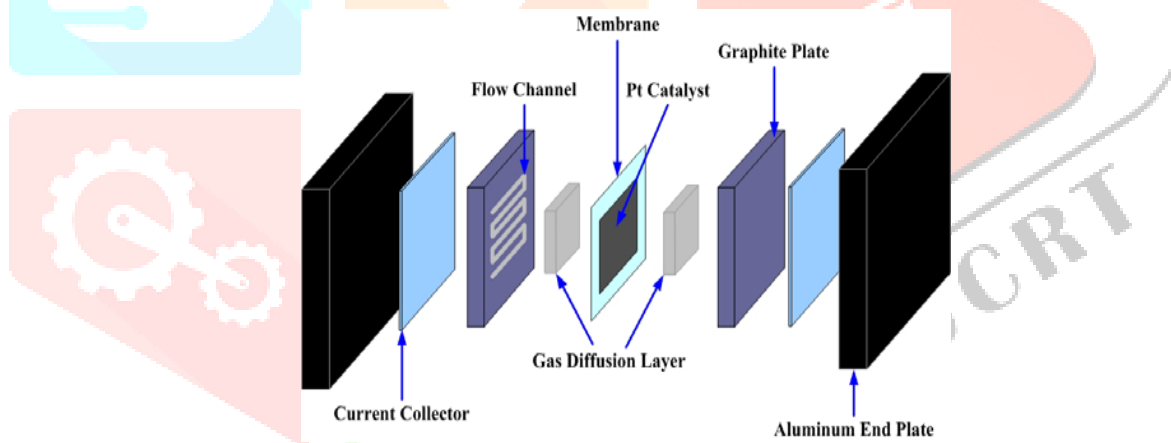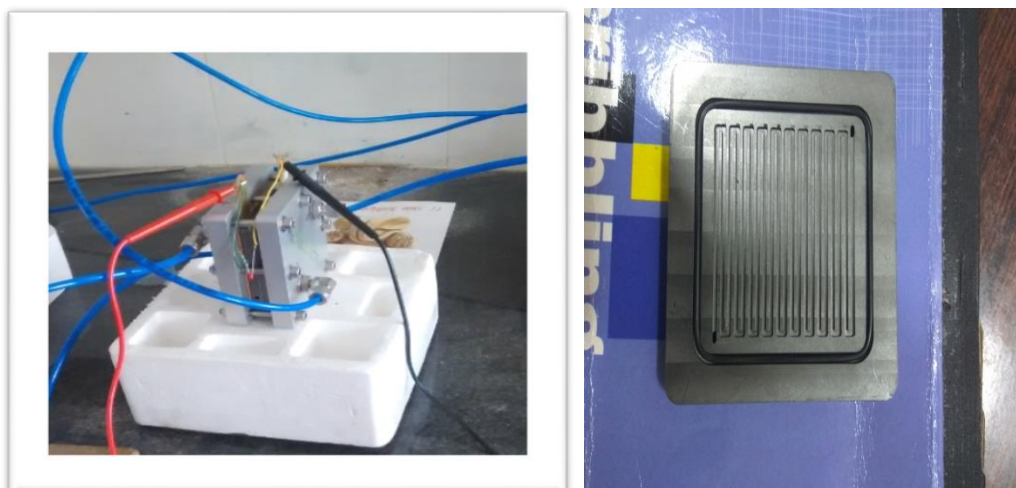
Fig.2 Components of PEMFC stack[5]

Fig.3 Different components of PEMFC stack at LIT, Nagpur

2. Materials & Methods

a. Specification of

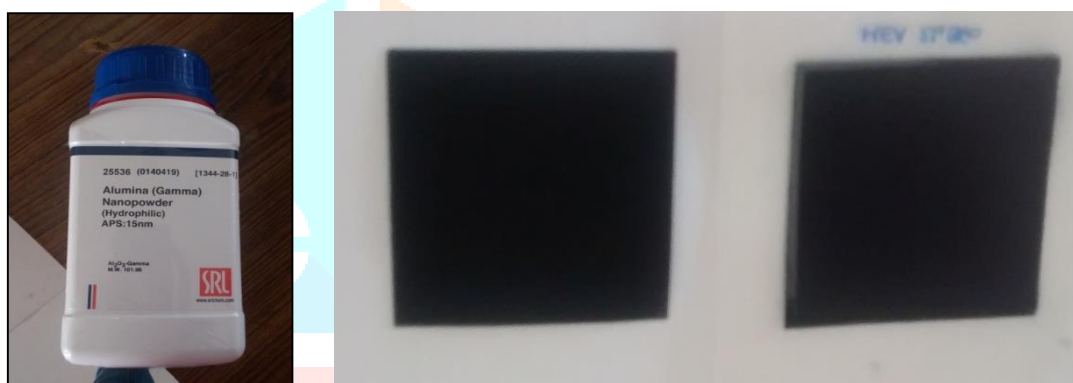### 1. MEA

Active area-25cm^2

Membrane-Nafion 117

Pt.loading 0.5 mgPt/cm^2 for no.24959,2.0 mg Pt/cm^2 for no.24960

2. Nanoparticle powder

Alumina (Gamma) Nanopowder (Hydrophilic)

APS:15 nm

Fig.4 a MEA b alumina nanoparticle powder

Experimental Set-up

The experimental set up also consists of storage cylinder of hydrogen. The O2 is used from air by compressing it and humidifying it. Both the sides' purifiers are attached. Voltmeter and multimeter is used to measure voltage and current change. Humidification chamber (Bubble Humidifying Bottles) is used to humidify H2 and O2 before they enter fuel cell.

 Fuel cell used in this experiment is manufactured by PAXITECH, FRANCE. The Membrane electrode assembly (MEA no.24959) consist of nafion membrane in combination with platinum loading of 0.5 mg pt/cm2, having 70%Pt/C ratio. The MEA is positioned between two graphite plates is pressed between two gold plated copper plates. The graphite plates are grooved for serpentine gas channels. Through which gasses flow. Hydrogen passes through anode side and oxygen passes through the cathode side.

The reactant gasses drawn from the storage tanks are humidified by bubbling though bottle humidifier. Fuel cell temperature and humidification temp. are controlled by lowering the temp. of humidifier. Purging is given at every 2 min. time interval.

EXPERIMENTAL METHOD

   The sequence of steps for each experimental run is as follows

1.   Connect the H$_2$ cylinder to the H$_2$ inlet of the stack via rotameter and gas humidifier

2.   Connect the air compressor to the O$_2$ inlet tube via rotameter and gas humidifier

3. Place humidifier on heating instrument so as to attain certain humidification temp.

4. Set H_2 flow rate .set the flow rate at 1.0 LPM

5. Set O_2 flow rate .set the flow rate at 2.5 LPM

6. H_2 inlet humidification temp. should be 55^0C-60^0C

7. Attach heating coil to the stack, maintain the stack temp. at 65^0C

8. Connect the load, voltmeter and ammeter

9.   Set the DC bulb connection to the fuel cell

10. Set the connection in series.

11. Set voltmeter in [V] and set ammeters in [μm]

12. Note down the current and voltage values after 5-5 min time interval

13. Collect the outlet water in the water collector beaker

14. Give the purging at each 3 min. time interval

15. Same procedure carried out with the (Al_2O_3 alumina (gamma) nanopowder (hydrophilic) for increasing the current density

16. Add nanopowder in the H_2 and O_2 bubbler

17. Stoichiometric ratio of H2/air is 1:2.5
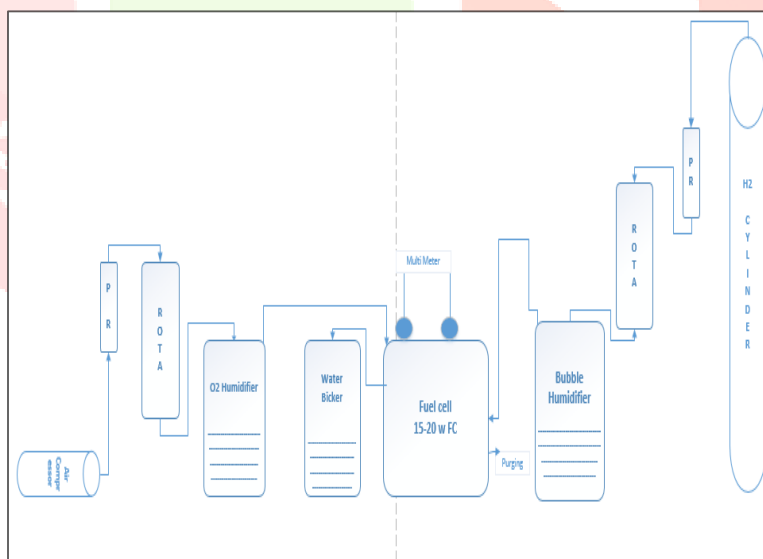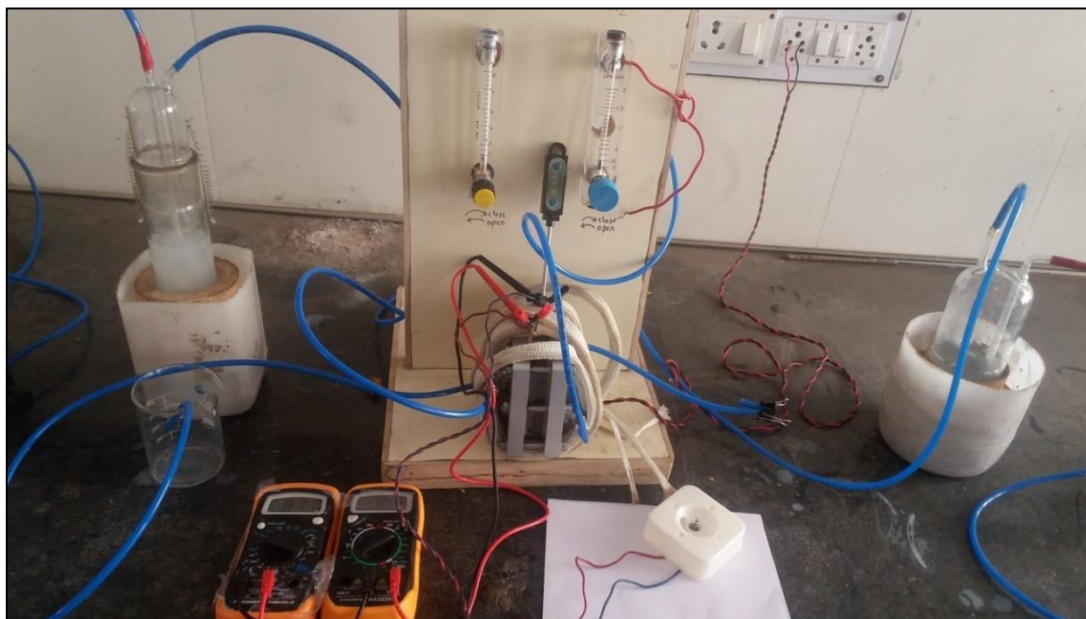
Fig.5 schematic representation of process

Fig.6 Experimental set up at LIT, Nagpur

3. Result and Discussion

Effect of platinum loading

Membrane is the core component of the PEM fuel cell. Triple roles of the polymeric membrane in the PEM fuel cells are as follows: charge carrier for protons, to separate of the reactant gases, and electronic insulator for not passing of electrons through the membrane{6}

The catalyst layer is in direct contact with the membrane and the gas diffusion layer. It is also referred to as the active layer. In both the anode and cathode, the catalyst layer is the location of the half-cell reaction in a PEM fuel cell. The catalyst layer is either applied to the membrane or to the gas diffusion layer. In either case, the objective is to place the catalyst particles, platinum or platinum alloy {7}.

In this expt. we have used two MEAs with different platinum loading: Pt. loading 0.5 mg Pt/cm^2 for no.24959, 2.0 mg Pt/cm^2 for no.24960 the result are as follows.

More the pt chargement on membrane more will be the hydrogen molecule splitting and also more will be cathode reaction rate.

Table 1.Observation with platinum loading of 2.0 mg Pt/cm^2

Sr.no	Cell Temperature (°C)	Current [μA]	Voltage [V]	Power [W] P=I × V	Current density (A/cm2)	Voltage efficiency $\varepsilon v = \frac{V}{E}$
1	65	00.7	0.866	6.062×10^{-7}	2.8×10^{-8}	70.40%
2	65	00.7	0.872	6.104×10^{-7}	2.8×10^{-8}	70.89%
3	65	00.8	0.874	6.992×10^{-7}	3.2×10^{-8}	71.05%
4	65	00.8	0.875	7×10^{-7}	3.2×10^{-8}	71.13%
5	65	00.8	0.876	7.008×10^{-7}	3.2×10^{-8}	71.21%
6	65	00.8	0.882	7.056×10^{-7}	3.2×10^{-8}	71.32%

Table 2 Observation with platinum loading of 0.5 mg Pt/cm^2

Sr no	Cell Temperature (°C)	Current [μA]	Voltage [V]	Power [W] P=I × V	Current density (A/cm2)	Voltage efficiency

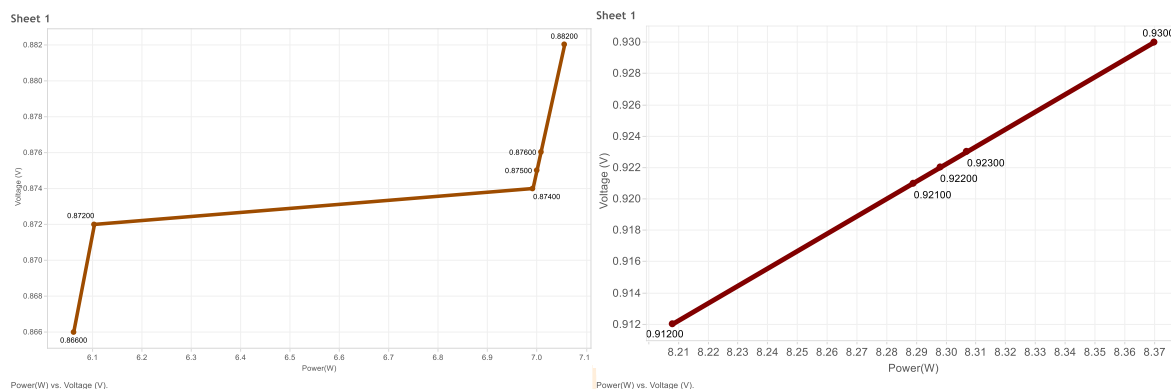|					$\varepsilon v = \frac{V}{E}$
1	65	00.9	0.912	8.208×10^{-7}	3.6×10^{-8}	74.14%
2	65	00.9	0.921	8.289×10^{-7}	3.6×10^{-8}	74.87%
3	65	00.9	0.922	8.298×10^{-7}	3.6×10^{-8}	74.95%
4	65	00.9	0.923	8.307×10^{-7}	3.6×10^{-8}	75.04%
5	65	00.9	0.930	8.37×10^{-7}	3.6×10^{-8}	75.60%

Fig 7 Power curve

It is observed that with more platinum loading initial rate of reaction will be more, but as ORR >HOR, water production will be more, which causes active sites blocking in membrane .so after some time of operation it was found that voltage has dropped. due kinetic losses. {8}

Table 3 With 0.25gm of nanopartical in O_2 humidifier and 0.25 gm of nanoparticle in H_2 humidifier (without load)

Sr no	Cell Temperature (°C)	Current [µA]	Voltage [V]	Power [W] P=I × V	Current density (A/cm2)	Voltage efficiency $\varepsilon v = \frac{V}{E}$
1	55	00.9	0.927	8.343×10^{-7}	3.6×10^{-8}	75.36%
2	55	00.9	0.936	8.424×10^{-7}	3.6×10^{-8}	76.09%
3	55	00.9	0.939	8.451×10^{-7}	3.6×10^{-8}	76.34%
4	55	00.9	0.940	8.46×10^{-7}	3.6×10^{-8}	76.42%
5	55	00.9	0.942	8.478×10^{-7}	3.6×10^{-8}	76.58%

Table 4 With 0.35gm of nanopartical in O_2 and in H_2 humidifier(without load)

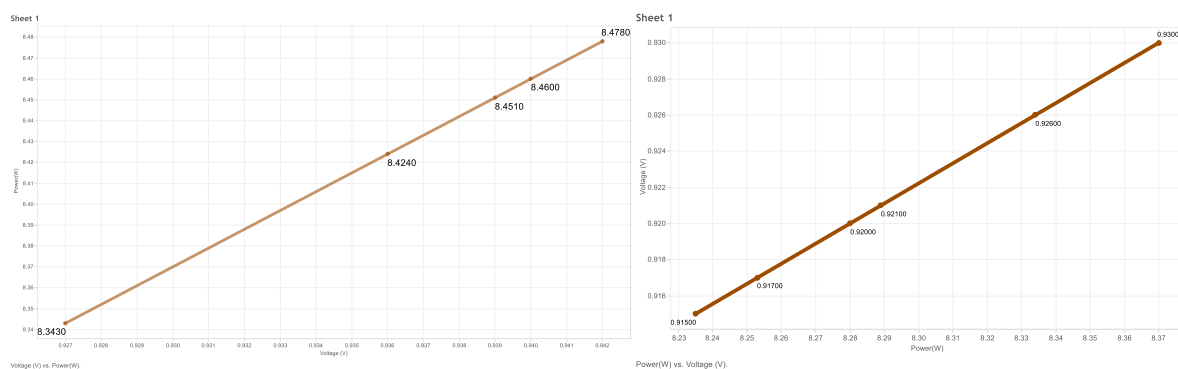| Sr no	Cell Temperature (°C)	Current [µA]	Voltage [V]	Power [W] P=I × V	Current density (A/cm2)	Voltage efficiency $\varepsilon v = \frac{V}{E}$
1	60	00.9	0.915	8.235×10^{-7}	3.6×10^{-8}	74.39%
2	60	00.9	0.917	8.253×10^{-7}	3.6×10^{-8}	74.55%
3	60	00.9	0.920	8.28×10^{-7}	3.6×10^{-8}	74.79%
4	60	00.9	0.921	8.289×10^{-7}	3.6×10^{-8}	74.87%
5	60	00.9	0.926	8.334×10^{-7}	3.6×10^{-8}	75.28%
6	60	00.9	0.930	8.37×10^{-7}	3.6×10^{-8}	75.60%

Fig.8 power curve

γ-phase nano-Al2O3 is with small size, high activity and low melting temperature, it can be used for producing synthetic sapphire with the method of thermal melting techniques; the nano-Al2O3 with large surface area and high catalytic activity, it can be made into microporous spherical structure or honeycomb structure of catalytic materials. These kinds of structures can be excellent catalyst carriers. it improves wettability & performance of PEMFC at low-humidity and low stack temperature condition.{9}

From the expt. it is found that with the increase in stack temperature &quantity of γ-alumina powder addition, the wettebility of cathode increases which causes reduction in cell performance due to water flooding. Which demonstrates the hygroscopic nature of γ-alumina particles, whether on the anode side initially it increases the performance then after some time voltage efficiency decreases.

Conclusion

- With an increase in stack temperature of fuel cell, the voltage value and current value are increases and voltage efficiencies of the cell increase. When the flow rate of air is 2.5LPM and when the flow rate of hydrogen 1 LPM till 65^0C.after that due to membrane dehydration, voltage starts to drop.

- It is found that initially membrane with2.0 mg Pt/cm^2 has shown good power output but as ORR>HOR,water production will be more which will travel to the anode side causes active site blockage

- With increase in the addition of γ-alumina nanopowder on cathode as well as anode side, the performance decreases. At the cathode it is due to the water flooding, at the anode it is due to the excess water absorption

- It is found that for good power output, pemfc single cell stack operating condition are platinum loading of 0.5 mg Pt/cm^2, With 0.25gm of γ-alumina nanopartical in O$_2$ humidifier and 0.25 gm of nanoparticle in H$_2$ humidifier. Humidification temp.of 55^0C.stack temperature of 65^0C.

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