RESEARCHERID
THOMSON REUTERS

[ICAME-2018] ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

PROTON EXCHANGE MEMBRANE FUEL CELL COMPONENTS FOR SINGLE CELL ASSEMBLY, TESTING AND ITS APPLICATIONS AS ALTERNATIVE POWER SOURCE

Syed Aslam*[1], Md. Masood[2] & Sudheer Prem Kumar[3]
[*1]Research Scholar Mech. Branch, JNTUH,
[2]Director R&D, Koman Research and Innovation Centre Mehdipatnam
[3]Professor Mech. Dept. JNTU Hyderabad

ABSTRACT

In the last few decades, fuel cells and in particular Proton Exchange Membrane Fuel Cells (PEMFCs) have gained more prominence as a zero emission power source. PEMFC convert chemical energy of Hydrogen(fuel) directly into electrical energy without combustion. Hydrogen fuel cells power vehicles without producing unwanted pollution and use no fossil fuel and help prevent environmental damage. Fuel cells have passed demonstration stage, and are marketable because of the remarkable benefits and worldwide research and development. Their efficiency is very high and offer a promising alternative to conventional energy conversion technologies for a wide range of applications. They can also be an interesting solution for many power sources. This paper provides summary of the components essential for fabricating PEMFC Single cell its testing and results and also presents an overview of Fuel Cell and their applications emphasizing that they are the future power sources for portable, automotive and stationary applications from few watts to MW range

Keywords: *PEMFC, Hydrogen fuel, zero emission vehicle, Automotive application.*

I. INTRODUCTION

Fuel Cell is an electrochemical device that converts chemical energy of fuel directly in Electricity, water and heat as by-product. Proton Exchange membrane fuel cell using hydrogen as fuel directly convert chemical energy into electrical energy without any emissions. The first commercial use of the prototype PEMFC was in 1960's Gemini space program by NASA. Due to its advantages of efficient energy conversion, high power density, environmental friendly, tremendous research programs worldwide promote PEMFC as power sources that could replace internal combustion engines for transportation and other stationary and portable applications from few watts to mega watts. Cost and durability are the main challenges for the development and commercialization of PEMFC. Depending on the use of electrolyte fuel cells can be classified in to the following types. Figure 1 shows the comparisons of Internal Combustion Engine(ICE) and Fuel cell efficiencies. The ICE depends on Carnot Cycle but Fuel Cell does not depend on it, hence its efficiency is high. The main components of Fuel Cell and their brief description is given below

Table-1 gives various types of fuel cells

S.No	**Type of fuel cell**	**Electrolyte**	**Temp. in °C**	**Fuel**
1	Polymer Electrolyte Membrane Fuel Cell (PEMFC)	Proton Exchange Membrane (Nafion, Gore)	**50-100**	$H_2 + O_2$/Air
2	Alkaline fuel cell (AFC)	potassium hydroxide (KOH)	**70-100**	$H_2 + O_2$
3	Phosphoric Acid Fuel Cell (PAFC)	phosphoric acid	**160-210**	H_2 rich gas + Air
4	Molten Carbonate Fuel Cell (MCFC)	High temperature compounds of salt carbonates CO_3 (sodium or magnesium)	**650**	H_2 rich gas + Air
5	Solid Oxide Fuel Cell (SOFC)	Solid ceramic compound (calcium or zirconium)	**800-1000**	H_2 rich gas + Air

6	Direct Methanol Fuel Cell (DMFC)	Proton Exchange Membrane (Nafion, Gore)	**50-100**	Methanol/Ethanol + O_2/Air
7	Regenerative Fuel Cell	Proton Exchange Membrane (Nafion, Gore)	**50-100**	H_2 + O_2/Air

II. MATERIALS

Catalyst

Platinum and Platinum Ruthenium Alloy are the most effective catalysts for oxidation and reduction reactions in a Proton Exchange Membrane Fuel Cell (PEMFC).

Electrodes

Anode and Cathode Gas Diffusion Electrodes (GDE) for an electrochemical device consist of catalyst loaded onto a gas diffusion layer (GDL). The most commonly used catalysts include carbon supported Platinum and Platinum/Ruthenium for the utilization of PEMFC. Electrodes for a fuel cell applications are generally hydrophobic to reduce flooding issue during fuel cell operation.

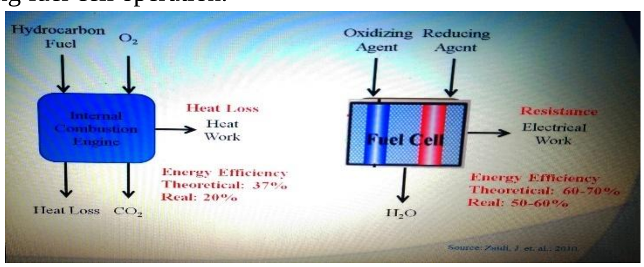


Figure1 shows comparison of efficiencies of IC Engine and Fuel cell

Gas diffusion layers

Gas Diffusion Layers (GDL) are key components in various types of fuel cells, including Proton Exchange Membrane (PEM), Direct Methanol (DMFC) and Phosphoric Acid (PAFC) stacks.

In fuel cells, this thin, porous sheet must provide high electrical and thermal conductivity in addition to controlling the proper flow of reactant gases (hydrogen and air) and managing the water transport out of the membrane electrode assembly (MEA). They provide enough mechanical strength to hold the MEA.
They are made of carbon fiber and made as carbon cloth or toray paper

Membrane electrode assemblies

Membrane Electrode Assembly (MEA) is the core component of a fuel cell that helps produce the electrochemical reaction needed to separate electrons. On the anode side of the MEA, a fuel (hydrogen, methanol etc.) diffuses through the membrane and is met on the cathode end by an oxidant (oxygen or air) which bonds with the fuel and receives the electrons that were separated from the fuel.

Catalysts on each side enable reactions and the membrane allows protons to pass through while keeping the gases separate. In this way cell potential is maintained and current is drawn from the cell producing electricity.
A typical MEA is composed of a Proton Exchange Membrane , two catalyst layers, and two Gas Diffusion Layers (GDL).
An alternative version of a membrane electrode assembly is the 3-Layer MEA which is composed of a proton exchange membrane with catalyst layers applied to both sides, anode and cathode. An alternative name for this type of MEA is a Catalyst Coated Membrane (CCM).

MEMBRANES

In order for a PEM fuel cell to operate, a Proton Exchange Membrane is needed that will carry the hydrogen ions, proton, from the anode to the cathode without passing the electrons that were removed from the hydrogen atoms. These membranes that conduct proton through the membrane but are reasonably impermeable to the gases, serve as solid electrolytes (vs. liquid electrolyte) for variety of electrochemical applications, and are commonly known as Proton Exchange Membrane and/or Polymer Electrolyte Membranes (PEM).

Bipolar plates

Each individual MEA produces less than 1 Volt under typical operating conditions, but most applications require higher voltages. Therefore, multiple MEAs are usually connected in series by stacking them on top of each other to provide a usable output voltage. Each cell in the stack is sandwiched between two bipolar plates to separate it from neighboring cells.

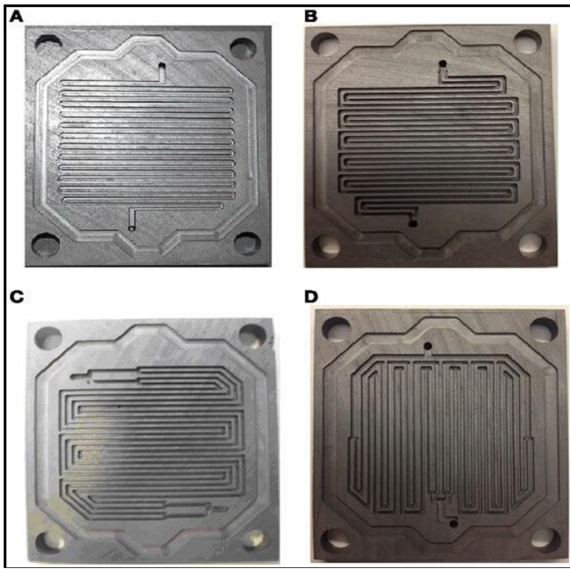


Figure 2 shows different gas flow fields

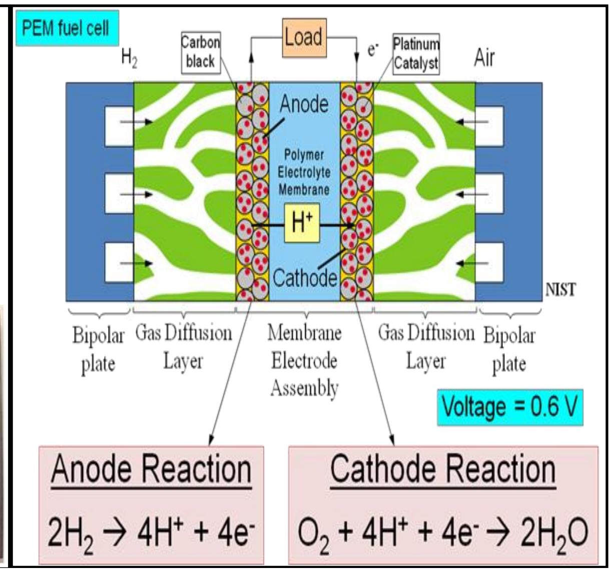


Figure 3 Shows working principle of PEMFC

These plates, which may be made of metal, carbon, or composites, provide electrical conduction between cells, as well as providing physical strength to the stack. The surfaces of the plates typically contain a "flow field," which is a set of channels machined or stamped into the plate to allow gases to flow over the MEA.Each cell in the stack is sandwiched between two bipolar plates to separate it from neighboring cells. These plates, which may be made of metal, carbon, or composites, provide electrical conduction between cells, as well as providing physical strength to the stack.

The surfaces of the plates typically contain a "flow field," which is a set of channels machined or stamped into the plate to allow gases to flow over the MEA. Additional channels inside each plate may be used to circulate a liquid coolant.The figure 2 shows four different types of flow channels in graphite plates. **(A)** a single serpentine channel: **(B)** double serpentine flow channels; **(C)** four serpentine flow channels; and **(D)** a symmetric arrangement of four serpentine flow channels.

III. ELECTRODE & MEA FABRICATION

The Toray Carbon Paper (TG-120) is hydrophobed with PTFE emulsion and sintered in an Oven at a temperature of 340^{o}C. A Micro Porous Layer (MPL) is formed on to Toray Carbon Paper containing PTFE and Carbon(Vulcan XC-72R) and sintered in an oven at 335^{o}C which is known as Diffusion Layer(DL). Thickness of this MPL is 30-40 µm.The Catalyst layer is Screen Printed on the Diffusion Layer forming Electrodes (Anodes and Cathodes) and sinter at 135^{o}C in an Oven under the inert gas atmosphere. The thickness of catalyst layer is 10 to 15 µm .

Figure 4 shows the schematic diagram for fabricating porous electrodes by the hybrid technique (Spraying & Screen Printing Techniques). Screen Printing Table and Furnace are used to fabricate and sinter electrodes respectively. After the Electrodes (Anode/Cathode) are sintered, Membrane Electrode Assembly is fabricated. The procedure for making MEA is as follows. Nafion Membrane "212" which is used as an Electrolyte is sand-witched between Anode and Cathode and assembled in steel plates and mounted in a Hydraulic Press and hot pressed at 135^0C-140^0C at 200kg/cm^2 pressure holding for 2 minutes. Figure 5 shows fabricated Membrane Electrode Assembly.

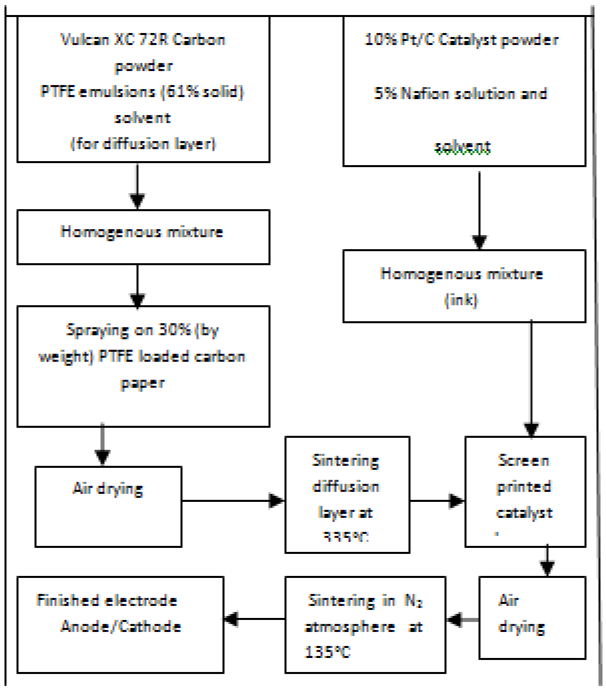


Figure 4 shows flow sheet for fabricating porous carbonelectrodes using hybrid spraying and screen printing technique

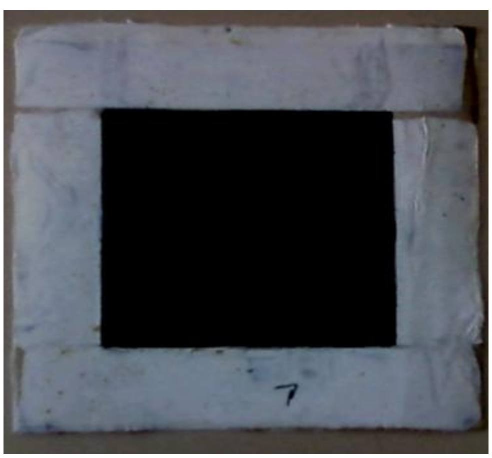


Fig. 5 Shows fabricated and sealed MEA

IV. SINGLE CELL ASSEMBLY AND TESTING

Experimental work has been done to demonstrate the technology of PEMFC by fabricating electrodes, forming membrane electrode assembly. Then assembling the MEA in the hardware to form Single Cell.

Figure 6 & 7 show the components of single cell and as assembly in the hardware respectively.The Membrane Electrode Assemblies were tested as single cells by assembling in the hardware and measurements were carried out using Fuel Cell Test station and DC Electric Bulbs/Multimeter as load

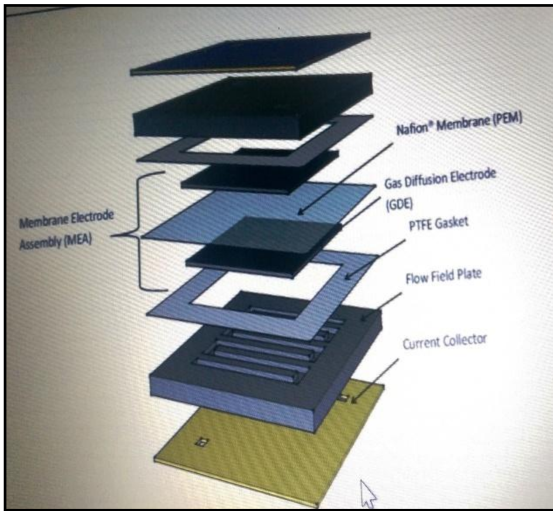


Figure 6 shows the components of single cell

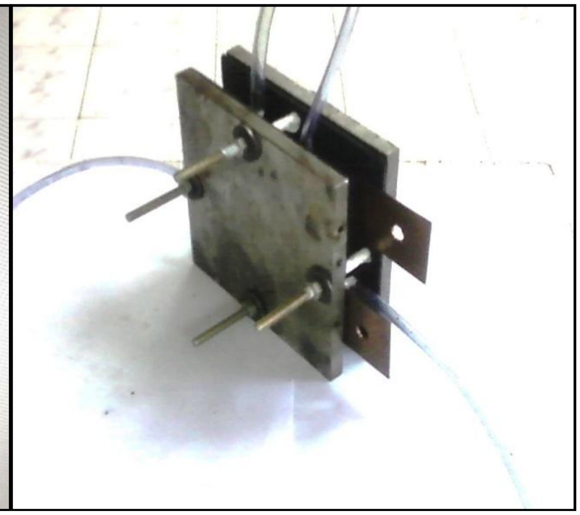


Figure 7 shows Single cell assembly in hardware

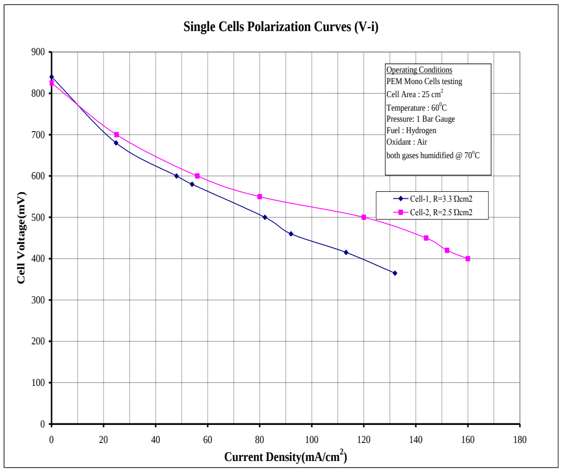
The results were evaluated and discussed.Cell-1 & Cell-2 were assembled in individual single cell hardware and tested for 4 days on Daily Start and Stop basis (10 AM to 4.30 PM) on the Test Bench.The performance of the cells improved on the second day. The data was collected and the polarization curves were drawn for the cells. Figure 8 Shows photo of PEM Fuel Cell tested on the Fuel Cell Test Station

V. EXPERIMENTAL RESULTS AND DISCUSSION

Measured polarization curves for single cells are presented in Figures 9 & 10. The single cell polarization curves showing the maximum current density of 160 mA/cm^2 and power generation of 1.6 Watts for Cell-2 and a current density of 120 mA/cm^2 and power generation of 1.2 Watts for Cell-1 without humidification.

Figure 8 Shows single cell being tested on fuel cell test station

The resistance of the cells was 2.5 Ωcm^2 and 3.3 Ωcm^2 for cell-2 & cell-1 respectively measured by Current Interrupt Method.There are other methods available for resistance measurement of single cell and stack.



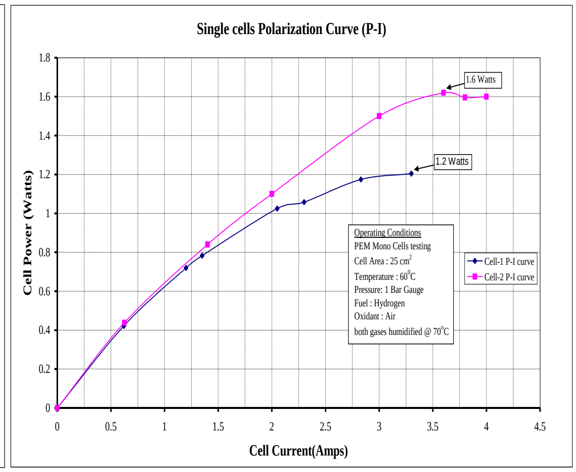


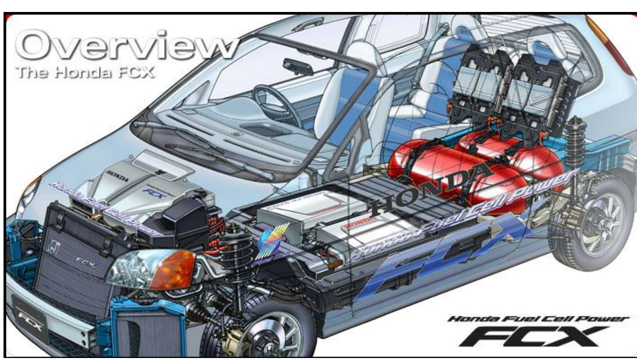
Figure 9 & 10 Shows the single cells Polarization Graphs of V-I& P-I

VI. FUEL CELL APPLICATIONS

Applications of Fuel Cell Technology as power source can be seen in

- Cars
- Buses
- Space Travel & Exploration
- Airplanes
- Submarines
- Off-grid Power Supply
- Combined Heat & Power
- Portable Electronic Gadgets

Fuel Cells application as power source are shown in few photos.



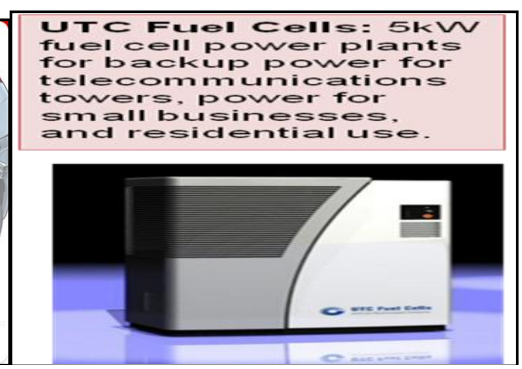


Figure 11 shows the PEMFC stack fitted in the car

Figure 12 shows backup power

ISSN 2348 – 8034
Impact Factor- 5.070

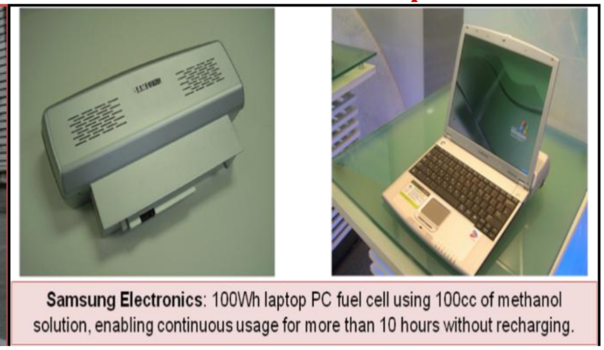


Figure 13 shows Mercedes-Benz: Citaro fuel cell bus Figure 14 shows DMFC as power source for Laptop

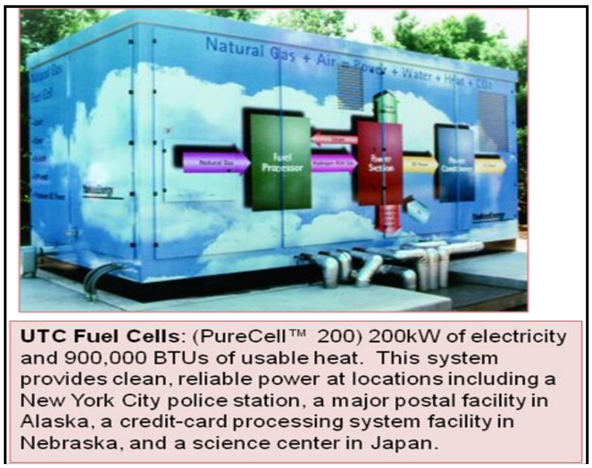


Figure 15 shows combined heat and power plant of PAFC

VII. CONCLUSIONS

The basic fabrication and methodology for fuel cell technology is presented. The performance of single cell producing power density of 0.158 W/cm^2 with humidification and 0.101 W/cm^2 without humidification is quite encouraging. Few Fuel cell applications are also shown. Future work will be pursued for optimization of PEMFC components by using CFD Modeling and simulation tool.

VIII. ACKNOWLEDGEMENT

The author would like to acknowledge the financial support received from All India Council for Technical Education(AICTE) and SNIST Management particularly, Mr. K.T. Mahi the Secretary and Dr. P.Narasimha Reddy for their guidance during the research project work undertaken at SNIST (2007-2011).

REFERENCES

1. *Fuel Cells-A Signpost to Future by Rumana Ali, Anser Pasha Materials Science and Engineering 376 (2018)*
2. *http:// www.fuelcellstores.com*
3. *Fuel Cell Fabrication and Testing Methodology for researchers in PEMFC by Syed Aslam, Md. Masood, Sudheer Prem Kumar at all India seminar on "Fuel Cell and Hybrid Vehicle Technology" 18-19 August,2017, Institute of Engineers India*
4. *Fuel Cells: A survey of current developments by* ***Dr. Jonathan Butler and Dr. Kerry Ann Adamson, Fuel Cell Today (FCT)****, 2013*

ISSN 2348 – 8034
Impact Factor- 5.070

5. *Frano Barbir, PEM Fuel Cells Theory & Practice-2005*
6. *Nguyen TV, White RE. A water and heat management models for proton-exchange- membrane fuel cells. J Electrochem Soc 1993;140:2178–86*
7. *http://www.Ballard.com, April, 2011*
8. *Review of proton exchange membrane fuel cell model by Atilla Bıyıkoglu, International Journal of Hydrogen Energy 30 (2005) 1181–1212.*