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Development and Analysis of Gas Diffusion Electrode in Polymer Electrolyte Membrane Fuel Cell

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ABSTRACT

Wireless Sensor Networks (WSNs) are widely used in different types of applications. Due to the open medium of these networks, they are vulnerable against the intrusions or attacks. Any adversary can have the opportunity to insert their attacks to dump the performance of the sensor nodes or the overall network. To identify the adversaries, Watchdog nodes are selected based on different mechanisms with limited assumptions. Once the adversary has the internal network knowledge, then the conventional monitoring mechanisms could be useless. This work provides resilient solution over these critical issues by selecting the watchdog nodes using On-Demand Dynamic Monitoring and Routing Protocol (ODDMRP) with secret key management techniques. Here, the watchdog node selection processes and the monitoring processes are kept secret against any type of adversary or against various attacks.
Keywords: ODDMRP, WSNs, MEA, CCM, PEMFC

I. INTRODUCTION

Proton exchange or polymer electrolyte membrane fuel cells (PEMFC) are considered to be the most promising power sources for portable and transportation applications since they electrochemically convert the chemical energy of hydrogen fuel into electrical energy with high efficiency and very low greenhouse gas emissions [1–4]. Due to the fact that PEMFCs need precious metals as the electro catalyst, decreasing the amount of precious metal without sacrificing the performance is necessary [5,6]. The key to reducing the loading of precious metals and maintaining the performance is to increase the catalyst utilization of the membrane electrode assemblies (MEA) of a PEM fuel cell. The MEA comprises a polymer electrolyte membrane and catalyst electrodes for hydrogen oxidation (anode) and oxygen reduction (cathode).

In a fuel cell system, the electrochemical reaction can only occur at "triple-phase boundaries", where the electrolyte, reaction material, and electrically connected catalyst particles contact together in a MEA [7, 8]. The triple-phase-boundary area in turn depends significantly on the fabrication procedure of MEA in addition to other important parameters such as catalyst loading and ionomer loading.

Normally there are two methods employed to Fabricate Membrane Electrode Assembly (MEA) - Conventional Method and Catalyst coated method (CCM). Initially the catalyst is made in ink form and the catalyst ink when coated on the MEA acts as the Electrodes during the process. In Conventional method, the prepared Catalyst ink is coated on two carbon papers. One carbon paper on the anode side and another on the cathode side. The ink is coated with a Spray gun according to the weight proportion to coat active area of 25cm^2. Then both the carbon papers are sandwiched between a proton exchange membrane commercially called as Nafion membrane and it is hot pressed to form a MEA.

In CCM method the catalyst ink is coated directly onto the Nafion Membrane which is the proton exchange membrane by the spray gun. Then it is hot pressed to form a MEA. It is reported that the MEA prepared by the CCM method provides better power density due to an extended catalyst/ionomer interface and improvement of catalyst utilization and also a higher current density.

Principle of PEM Fuel Cell

In PEM cells, the chemical energy is converted to electrical energy through Direct Electrochemical Reaction without Combustion. The Key part of a PEM fuel cell, which is known as a membrane electrode assembly (MEA), consists of a polymer electrolyte in contact with an anode and a cathode on either side. To function, the membrane must conduct hydrogen ions (protons) and separate either gas to pass to the other side of the cell. The splitting of the hydrogen molecule is done using a platinum catalyst.

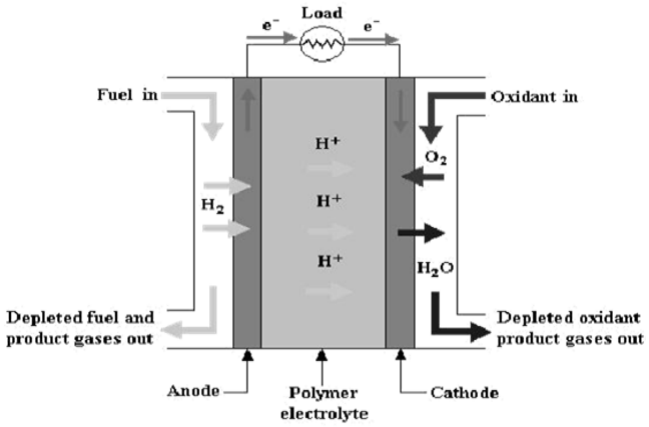

Figure 1. Principle of PEM fuel cell

II. METHODS AND MATERIAL

Experimental

A. Catalyst Ink Calculation

- 40% Pt/C Material is used as the catalyst(It is taken By weight proportion to coat active area of 25cm2, which is (0.75mg/cm2 * 25= 18.75mg) so 1.8g is taken. 40% platinum/Vulcan carbon = 720mg of Pt/ 1080mg of C in 1.8g.
- The Calculation for Platinum is given by, Atomic Wt of Platinum/ Molecular wt of Platinum.
- Atomic Weight of Platinum is 195.084. Therefore: (195.084/195.084)*720= 720mg of pt.
- Thus 720mg of platinum combined with 1080mg of Vulcan carbon powder is weighed in scale and taken as powder form.

B. Catalyst Ink Synthesis Procedure

For 40% Platinum/C:

- Add the catalyst weighing 18.75mg in the beaker and mix it with 0-1ml of distilled water till it forms a paste.
- Then add 0.2ml nafion solution on the paste and stir it with magnetic stirrer for 10-15 mins.
- Add 2ml Isopropyl alcohol on the paste drop by drop using a micro pipette.
- Keep it in Sonicator for 15-20mins.
- Then add 8-10ml of distilled water along with few drops of Isopropyl Alcohol till the paste becomes a slurry and is being able to be injected through the Spray gun.
- Beaker is kept in magnetic stirrer with Teflon beads and stirred for another 10-15 mins.
- Then for another 10-15mins in sonicator.
- The Beaker should be covered with Aluminum foil on the top during the process.

C. Conventional Method & Meapreparation Method

The 5 Layer MEA is actually 5 layers sandwiched together. They are as follows (anode side carbon paper, catalyst, membrane, catalyst and cathode side carbon paper). Each are individual layers comprised as 5 layer MEA. The prepared catalyst is protected with aluminum foil. The catalyst has to be coated on two carbon papers(1 anode side & 1cathode side).The process is done by spray coating method using pen gun. The pen gun works with nitrogen gas as a medium. Initially the pen gun is cleaned with few drops of isopropyl alcohol to clean it throughly. Then the catalyst ink is poured in the pen gun cap and the catalyst is coated on the 25cm2 active area carbon paper in a controlled manner. The carbon paper is dried at 60 ◦C for 3-4 hrs. Then both the carbon papers are kept at the opposite sides of the Nafion Membrane and sandwiched in the HOT Press Method under 110 ◦C for 90s. Then a single cell if formed with the prepared Membrane Electrode Assembly (MEA) and kept in the FCT-50S Fuel cell Testing Apparatus to find the performance. The Conditioning Process is done to enhance the Performance of the cell. Then the results will be obtained and its electrochemical studies are done using Cyclic Volta metric Test to find the output Parameters. Before the process the proton exchange membrane

(PEM, Nafion 112, DuPont) were treated according to the standard procedure of 30 min in 5 wt. % H2O2 solution at 80 ◦C, 30 min in distilled water at 80 ◦C.

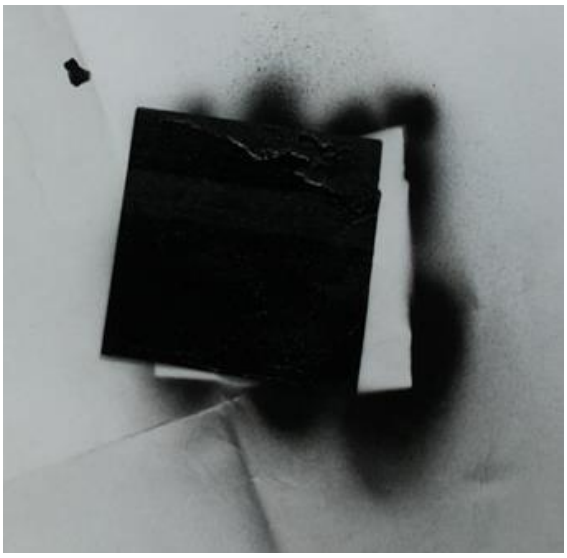

Figure 1. Carbon paper coated with the Catalyst Slurry.

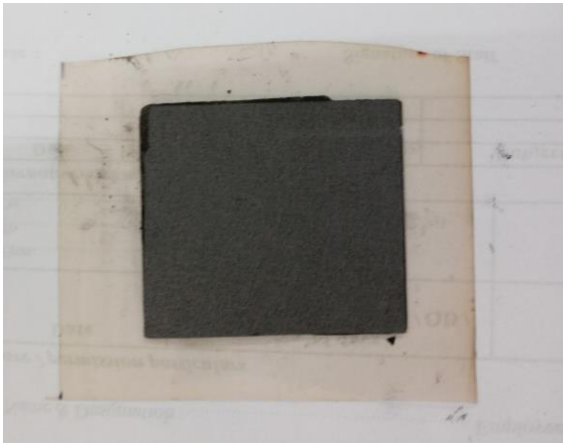

Figure 2. 5 Layer MEA prepared by the Conventional Method

D. Conditioning Process

In order to properly humidify the MEA, that has been dried out during the hot pressing stage, a conditioning or activation Procedure is done initially. This conditioning procedure includes 3 steps. Initially using voltage pulse program in the software, a constant voltage of 0.6 V is held for 60 min. In step 2 by a cyclic looping process, voltage of 0.7 is held for 20 min following it voltage of 0.5 is maintained for same duration of 20 min. This stepping down and stepping up of voltage from 0.7 to 0.5 and 0.5 to 0.7 is performed until the current value in the particular voltage reaches a peak. This method ensures that the MEA is performing at its peak power value and that a majority of the catalyst sites are activated.

E. Cyclic Voltammetric Test

Cyclicvoltammetryor is a type of is a type of electrochemical measurement to study the catalyst Performance. In a cyclic voltammetry experiment, the working electrode potential is ramped linearly versus time. The current at the working electrode is plotted versus the applied voltage (i.e., the working electrode's potential) to give the cyclic polarization curve.

E. CCM Method

For the preparation of MEA by the CCM method, the Prepared catalyst Ink is Directly coated onto the Nafion Membrane in a thin film on both sides (Whole active area) by spraying using the Pen spray gun as in Spray coating method, then it is dried at 60 ◦C for 3-4hrs followed by a 90 ◦C in N2 atmosphere for 3 min. then it is sandwiched using Hot Press under 120 ◦C for 3mins. The MEA is kept in the single cell and the performance is tested using the FCT-50s Testing Apparatus.

III. RESULTS AND DISCUSSION

The result for the conventional 5 layer GDL MEA was obtained from the Process. The parameters to be found (POWER DENSITY, CURRENT DENSITY AND VOLTAGE) are got from the Result and it is described in terms of graph.

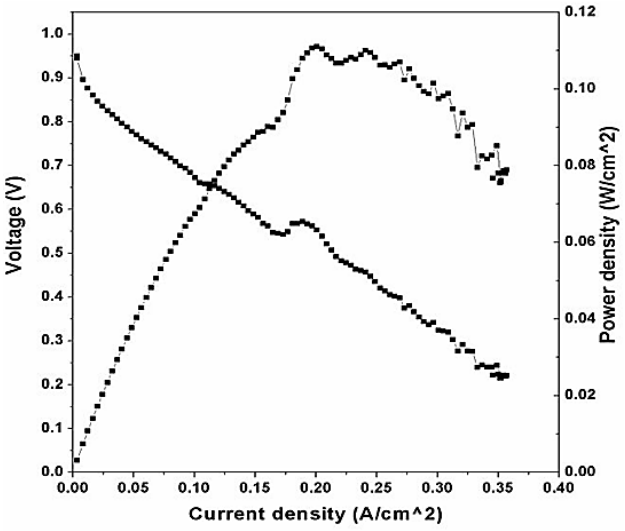

Figure 3. 5 Layer MEA result.

IV. CONCLUSION

The 5 Layer MEA was prepared from the following procedures and the result is obtained which is described in the graph. The obtained result is Peak Current Density value is 0.3544(A/cm^2), Peak Power Density value is 0.1110424(W/cm^2) and the Peak Power value is given as 2.77606 W. The Performance of the single cell using the prepared 5 Layer MEA (Power Density, Current Density and Voltage) are obtained and it is plotted in the graph. The same procedure will be done to prepare the 3 Layer GDL MEA using the same catalyst material by Catalyst Coated Membrane Method (CCM) and both the results will be compared for better performance of the cell.

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