EFFECT OF POWDER POLYPROPYLENE SIZE ON THE PROPERTIES OF GRAPHITE/STANNUM/POLYPROPYLENE COMPOSITE FOR BIPOLAR PLATE

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DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

Signature :...................................

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ABSTRACT

Bipolar plates are the main components in a Proton Exchange Membrane Fuel Cell (PEMFC). Their main function is to conduct electricity in the fuel cell while still can withstand the force experienced due to the nature placement of the bipolar plates inside a PEMFC. A good bipolar plates must have good electrical conductivity and also good mechanical strength. The development of more lightweight and more advance polymer composite bipolar plates leads to further experimentation of maximizing the electrical conductivity and mechanical strength of the bipolar plates to the optimum level. In this research project, materials used to fabricate the bipolar plates are Graphite (Gr), Stannum (Sn) and Polypropylene (PP). Gr and Sn act as fillers while PP acts as binder. All the raw materials used to fabricate the bipolar plate are in powder form. The weight percentage is set to be 80 wt% for Gr and Sn, and the remaining 20 wt% for PP. Three different compositions of Gr/Sn are 70/10, 65/15 and 60/20 for every PP with the size of 500 µ, 250 µ and 100 µ which make a total of 9 samples. Ball mill machine is used to mix the materials before being hot pressed into a bipolar plate. The effect of different PP size shows the difference in electrical conductivity. The biggest PP powder size of 500 µ shows higher electrical conductivity compared to smaller size of PP powder regardless of different composition of Gr and Sn. The highest reading is 193.39 S/cm which is more than 100 S/cm of United States Department of Energy (US DOE) basic requirement. Both shore hardness and bulk density increases as the size of PP powder decreases and all the samples pass the basic requirement by the US DOE for both mechanical properties. The maximum value obtained is 62.0 for shore hardness test and 1.896 g/cm^3 for bulk density test.

ABSTRAK

Plat dwi kutub merupakan komponen utama di dalam “Proton Exchange Membrane Fuel Cell” (PEMFC). Fungsi utama adalah untuk mengalirkan elektrik di dalam sel bahan api dan masih mempunyai daya tahan untuk kekal di dalamnya. Plat dwi kutub yang bagus mesti mempunyai pengaliran elekrik dan juga kekuatan mekanikal yang baik. Pembinaan plat dwi kutub polimer komposit yang lebih ringan dan lebih maju membawa kepada uji kaji lanjut untuk memaksimumkan pengaliran elektrik dan kekuatan mekanikal plat dwi kutub itu kepada tahap optimum. Dalam projek penyilidikan ini, bahan-bahan yang digunakan untuk membuat plat dwi kutub ini ialah Grafit (Gr), Stannum (Sn) dan Polypropylene (PP). Gr dan Sn adalah sebagai pengisi manakala PP pula sebagai pengikat. Semua bahan-bahan mentah yang digunakan untuk membuat plat dwi kutub ini adalah dalam bentuk serbuk. Peratusan berat untuk Gr dan Sn ialah 80% dan baki 20% ialah PP. Tiga komposisi yang berbeza daripada Gr/Sn ialah 70/10, 65/15 dan 60/20 untuk setiap saiz PP iaitu 500 μ, 250 μ and 100 μ yang menjadikan 9 sampel jumlah keseluruhannya. Mesin “ball mill” digunakan untuk mencampurkan bahan-bahan tersebut sebelum dimampat serta dipanaskan menjadi plat dwi kutub. Kesan saiz PP yang berbeza menunjukkan perbezaan dalam keupayaan pengaliran elektrik. Saiz serbuk PP yang terbesar iaitu 500 μ menunjukkan pengaliran elektrik yang tinggi berbanding saiz serbuk PP yang lebih kecil tanpa mengira perbezaan komposisi Gr dan Sn. Bacaan tertinggi ialah 193.39 S/cm iaitu lebih daripada 100 S/cm iaitu keperluan asas dari United States Department of Energy (US DOE). Kedua-dua kekerasan “shore” dan ketumpatan pukal meningkat apabila berkurangnya saiz serbuk PP dan kesemua sampel lulus dalam keperluan asas dari US DOE untuk kedua-dua sifat mekanikal tersebut. Nilai maksimum yang diperolehi ialah 62.0 untuk ujian kekerasan “shore” dan 1.896 g/cm^3 untuk ujian ketumpatan pukal.

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LIST OF ABBEREVATIONS

PEMFC	Proton Exchange Membrane Fuel Cell
US DOE	United States Department of Energy
CPCs	Conductive Polymer Composites
Gr	Graphite
Sn	Stannum
PP	Polypropylene
rpm	Revolutions Per Minute
ASTM	American Society for Testing and Materials

LIST OF SYMBOLS

^{o}C	=	Degree Celsius
Nm	=	Newton Meter
μ	=	Micron
μm	=	Micrometer
ϕ_c	=	Volume Fraction
wt%	=	Weight Percentage
mA	=	Miliampere
g/cm^3	=	Density, gram per cubic centimeter
Ωcm	=	Resistivity, Ohm-centimeter
σ_f	=	Flexural Strength

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The existence of fuel cells nowadays really gives a big impact as a leading role in the economy. With the advance developing technology in fuel cells, the impact of energy consumption is reduced on the environment. Fuel cells represent one of the best solutions especially in addressing the issue of irregular behavior of renewable sources. The proton exchange membrane fuel cells (PEMFCs) are converting hydrogen and oxygen into electricity at low operation temperature which is below than 100^{o}C [1]. The schematic diagram of PEMFC is shown in Figure 1.1. Besides, the cost and durability of the fuel cells remain the major parameters to improve for the extensive usage and to improve liability.

Great efforts are put especially on bipolar plates, which are considered as the main part of a fuel cell stack [2]. Bipolar plates is the most important part of the stack which contributes about 80% of the total weight [2] and nearly half the cost of a fuel cell which is 30 to 40%[3]. There are many functions of the bipolar plates. The plates should homogeneously distribute gases over the area of the cell. It also separates the fuel and oxidant gases and prevents gas leakage. Besides, it collects the current produced in the electrochemical reactions and discharges the water that produced from the reactions. Last but not least, the bipolar plates are there to ensure the mechanical strength of the stack. As the bipolar plates almost determine the overall mechanical strength of the stack of a fuel cell, it is quite important to use material with relatively better mechanical strength for the bipolar plates. Figure 1.2 shows the position of the bipolar plate inside the stacking of a fuel cell and more bipolar plates shown in Figure 1.3.

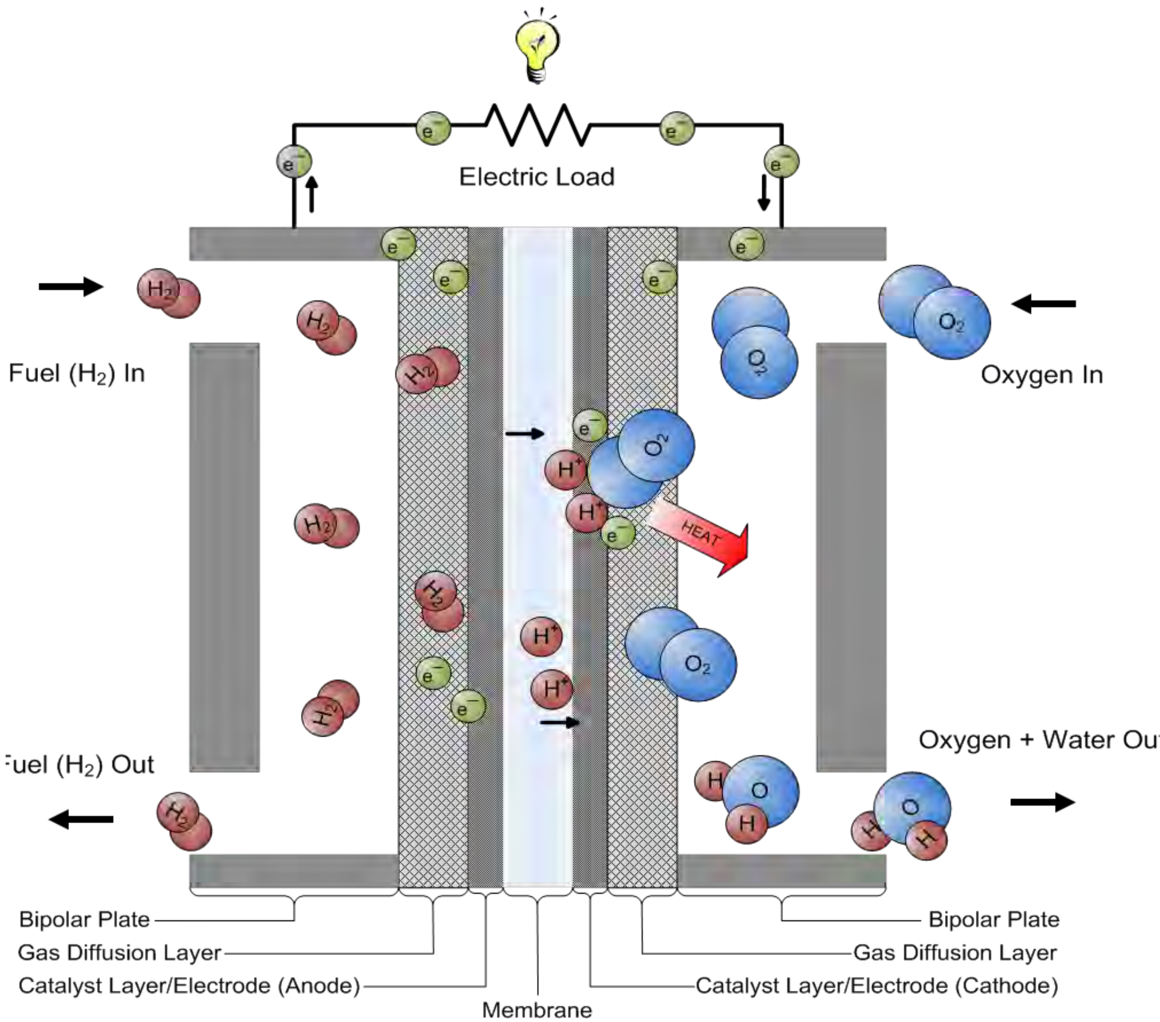

Figure 1.1: Schematic diagram of a PEMFC [4]

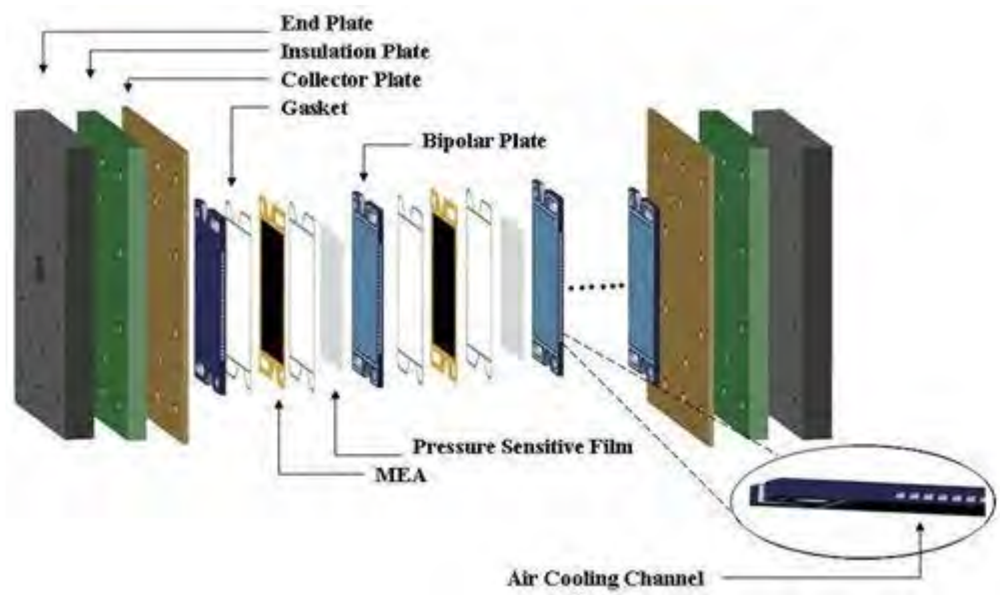

Figure 1.2: The location of bipolar plate inside a fuel cell [5]

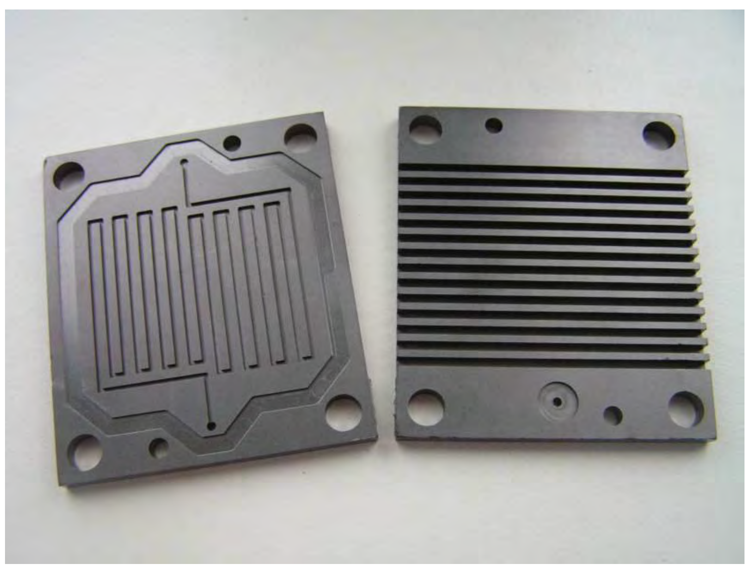

Figure 1.3: Real image of bipolar plates

The material selection to fabricate the bipolar plates plays a very important role in determining the quality, performance and cost of a fuel cell. Each material has its own advantages and disadvantages over the other material. As a benchmark to material selection for bipolar plates, the bipolar plate's application should present a balance of various physical and chemical properties. These requirements are issued by the Department of Energy and several companies, which the developments of bipolar plates are based [6]. The bipolar plates that will be fabricated in this experiment are polymer composite material.

1.2 PROBLEM STATEMENT

Bipolar plates in fuel cell are key factors of overall performance and mechanical strength of the fuel cell. As long as the electrical and mechanical properties are concerned, the polymer composite material for the bipolar plates is used and will be tested with electrical and mechanical tests to gauge its performance. The combination of carbon based filler and metal filler as conductive fillers in fabricating conducting polymer composite is become an interesting and alternative in produce bipolar plate. Normally Graphite (Gr) will be used as main filler, Stannum (Sn) as second filler and Polypropylene (PP) is used as binder. The problem is that the best size of PP powder is still not determined for the fabrication of the bipolar plates for the best performance in electrical and mechanical performance [7]. To overcome this problem, PP powder sizes are varied to test each of the combination of the polymer composite to determine the best PP powder size. Thus, the manipulated variable in this project is the size of the PP powder used for fabricating the bipolar plates. Certain sizes of PP powder are used to differentiate the electrical and mechanical properties since the polymer composite materials remain the same throughout this project.

In this project, Gr and Sn act as fillers while PP acts as binder for the bipolar plate's fabrication. This combination of materials will be tested to investigate the two main important aspects for bipolar plates in fuel cell which are the mechanical properties and the electrical properties. Polymers are commonly electrical insulators, but this time it is combined with Gr and Sn that act as electrical conductors which mixing the limitations of metal and composites.

1.3 OBJECTIVES

The objectives of this project are as follows:

1. To study the effect of PP powder size on the properties of Gr/Sn/PP composite.
2. To determine the suitable process parameter for Gr/Sn/PP composite.

1.4 SCOPE OF PROJECT

The scope of this project is to study the effect of PP powder size on the electrical and mechanical properties of Gr/Sn/PP composite. In order to determine the effect of PP powder size, several size of PP powder (100 up to 500 μ) will be used in Gr/Sn/PP composite. In this project, the specimens will be fabricated using the hot press with the temperature of 175°C. Before the fabrication process, the mixture of Gr, Sn and PP will be mixed by using ball mill. The test such as electrical conductivity, bulk density, and shore hardness test will be performed to determine the electrical and mechanical properties of Gr/Sn/PP composite.

CHAPTER 2

LITERATURE REVIEW

2.1 CONDUCTIVE POLYMER COMPOSITES

A composite is a combination of more than one or several materials joined together meanwhile conductive polymer composites (CPCs) is composites with the combination of electrical conductive filler with a polymer that is an electrical insulator. Not all polymers are electrical insulator. There are some polymers which are electrical conductive. Polymer like PP is an electrical insulator because it does not have conjugated chain structures like the other that are electrical conductive. In the case of CPCs, polymer like PP can become conductive. This is achieved by adding electrical conductive filler and combined it with the polymer as composites.

There are several parameters in order to determine the properties of the CPC. One of them is the percolation threshold that is the volume fraction (ϕ_c) over which leads the CPC to be conductive.

2.1.1 Percolation Threshold

Percolation threshold is a mathematical concept related to percolation theory, which is the development of long range connection in random systems. The percolation theory describes the behavior of connected clusters in a random graph. Flory in 1941 and Stockmayer in 1943 developed the percolation processes to describe how tiny branching molecules react and form very huge macromolecules [8]. The connected cluster is the main mechanism of how the composites to be conductive through the mixing of conductive fillers with an electrical insulating binder.

The percolation threshold that is the volume fraction (ϕ_c) has been studied in greater depth and was found to be sensitive to several parameters such as the surface energy of the filler and the polymer matrix [9,10], crystallinity [11,12] and exclusion volume. Figure 2.1 shows the schematics diagram of percolation pathway with an example diagram of combination of polymer and filler as a conductive network.

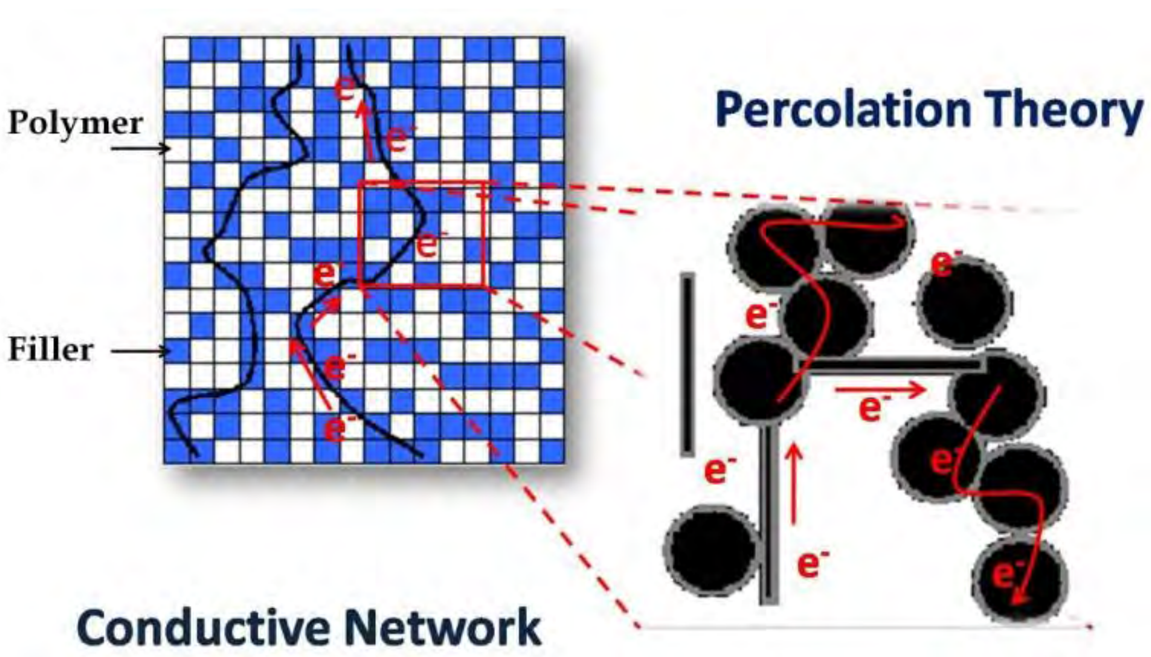

Figure 2.1: Schematics diagram of Percolation Pathway [13]

2.2 BIPOLAR PLATE

Bipolar plates are traditionally fabricated with Gr and have been used in many applications. Besides Gr, later in the production of bipolar plates, the technology of using metallic bipolar plates and polymer composite bipolar plates emerged due to several reasons. There are quite a number of advantages and disadvantages of using these different types of materials for bipolar plates.

2.2.1 Graphite Bipolar Plate

One material that has been extensively used in fabricating bipolar plates is Gr which is based on carbon material. This is because of one of its properties that it is so stable against chemical inside the fuel cell. One of the major disadvantages on fabricating graphite bipolar plates is the high price of the Gr material and still no way to decrease the cost nowadays [14,15]. Figure 2.2 shows the graphite bipolar plate while Table 2.1 shows the advantages and also the disadvantages of fabricating bipolar plates by using Gr.

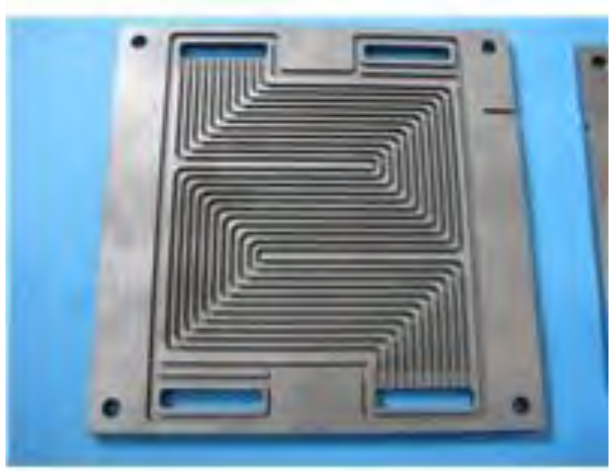

Figure 2.2: Graphite bipolar plate

Table 2.1: Advantages and Disadvantages of Graphite Bipolar Plates [16]

Advantages	**Disadvantages**
➢ Strong resistance to corrosion ➢ Low bulk resistivity ➢ Low specific density ➢ Low electrical contact resistance	➢ Very costly ➢ Difficult to be machined ➢ Porosity problem ➢ Low mechanical strength due to brittleness

2.2.2 Metallic Bipolar Plate

In PEMFC, the metallic type of bipolar plate is also being used as it offers more advantages compared to the conventional and traditional bipolar plate fabricated from Gr. Some of the advantages are low cost material, better electrical conductivity, easy to be machined and it also has strong mechanical strength. Because of the high strength, the thickness of the bipolar plate can be reduce overall, hence making it smaller in volume and weight which lead to other advantages. Metallic bipolar plate also has high resistance to corrosion when using materials such as titanium and stainless steel to fabricate the bipolar plate. However, one disadvantages of the metallic bipolar plate is sometimes the metal ion will dissolve and will poison the membrane. It is important to improve the surface quality of the plate and thanks to Oak Ridge National Laboratory when they came up with technologies to enhance the surface quality of metallic plate in the year 2002 [17]. To summarize the advantages and disadvantages of metallic bipolar plate, Table 2.2 is provided to show them clearly. Figure 2.3 shows the appearance of metallic bipolar plate.