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"I declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials)"

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THE EFFECT OF STAINLESS STEEL ON THE PROPERTIES OF GRAPHITE-POLYPROPYLENE COMPOSITE FOR BIPOLAR PLATE

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This report is submitted to Faculty of Mechanical Engineering as a requirements to get award of Degree of Mechanical Engineering (Structure & Material)

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JUNE 2013

DECLARATION

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

Signature : ....

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ABSTRACT

Over the past decade, rapid progress has been made in the understanding and development of Conductive Polymer Composites (CPC) as conducting materials. This project is aimed to study the effects of stainless steel (St) loading on the electrical and mechanical properties of Graphite (G)/ Stainless steel (St)/ polypropylene (PP) composite of bipolar plates for polymer electrolyte membrane fuel cells (PEMFC). St is selected as second filler because it offers good electrical conductivity, high bulk thermal conductivities, good corrosion resistance and constant particle shape. The analysis of the G/St/PP composites ratio and the properties of G, St and PP together with the impact of Graphite (G) as a main filler and Stainless Steel (St) as second filler whereas polypropylene (PP) as a binder has been carry out. The impact of fillers on the composite properties was evaluated as well as the ratio of the weight percentage (wt %) of the composite with 80% for multi-filler material and 20% binder material. The St wt % is vary from 5 wt % up to 30 wt % of total wt % of multi-filler materials. After formation of composite through compression molding, the effects of St in G/St/PP composite have been determined through various tests such as electrical conductivity, flexure strength, density and hardness before can be used as composition of G/St/PP composite for bipolar plate. The result showed the analysis for Flexural Strength, Bulk Density and Shore Hardness meet the required characteristics of bipolar plate as in the Department of Energy (DOE). But for electrical conductivity, the results showed a very slight increase which is less than 100S/cm.

ABSTRAK

Lebih sedekad yang lalu, kemajuan pesat telah dibuat dalam memahami dan pembangunan konduktif Polimer Komposit (CPC) yang mengendalikan bahan-bahan. Projek ini bertujuan untuk mengkaji kesan daripada keluli tahan karat (St) pada sifat-sifat elektrik dan mekanikal Grafit (G) / keluli tahan karat (St) / polipropilena (PP) komposit plat dwikutub bagi polimer elektrolit sel bahan api membran. St dipilih sebagai pengisi kedua kerana ia menawarkan kekonduksian elektrik yang baik, konduktiviti haba yang tinggi, ketahanan kakisan yang baik dan bentuk zarah yang berterusan. Analisis nisbah komposit G / St / PP dan sifat-sifat G, St PP dan bersama-sama dengan kesan Grafit (G) sebagai pengisi utama dan keluli tahan karat (St) sebagai pengisi kedua manakala polipropilena (PP) sebagai pengikat telah menjalankan. Kesan pengisi pada sifat-sifat komposit telah dinilai serta nisbah peratusan berat (% berat) dengan 80% untuk bahan pelbagai pengisi dan 20% bahan pengikat. Berat St% yang berbeza-beza dari 5% sehingga 30% daripada jumlah berat bahan pelbagai pengisi. Selepas pembentukan komposit melalui pengacuan mampatan, kesan St dalam G / St / PP komposit telah ditentukan melalui pelbagai ujian seperti kekonduksian elektrik, kekuatan lenturan, kepadatan dan kekerasan sebelum boleh digunakan sebagai komposisi G / St / PP gubahan plat dwikutub. Hasilnya menunjukkan analisis untuk kekuatan lenturan, ketumpatan dan kekerasan memenuhi ciri-ciri yang diperlukan plat dwikutub oleh Jabatan Tenaga. Tetapi bagi kekonduksian elektrik, keputusan menunjukkan peningkatan yang sangat sedikit iaitu kurang daripada 100S/cm.

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LIST OF SYMBOL

PEMFC	= Proton Exchange Membrane Fuel Cell / Polymer Electrolyte Membrane Fuel Cell
PEM	= Polymer Electrolyte Membrane
BPs	= Bipolar Plate
DC	= Direct Current
H2O	= Hydrogen
O2	= Oxygen
MEA	= Membrane Electrolyte Assembly
G	= Graphite
St	= Stainless Steel
PP	= Polypropylene
PPS	= Polyphenylene sulfide
PVDF	= Polyvinylidene fluoride
CPCs	= Conductive Polymer Composites
IPCs	= Inherently Conducting Polymers
SPEs	= Solid Polymer Electrolytes
Cr	= Chromium
Ni	= Nickel
Mo	= Molybdenum
LDPE	= Low-Density Polyethylene
HDPE	= High-Density Polyethylene
MFR	= Melt Flow Rate
MFI	= Melt Flow Index
DOE	= US-Department of Energy

LIST OF ABBREVIATION

Wt.%	= Weight Percentage
S/cm	= Siemens/centimeter
MPa	= Mega Pascal
Cm	= centimeter
µA	= micron Ampere
g/cm^3	= gram/centimeter3
W·m−	= Watt per metre
µA cm^ (-2)	= Micro ampere(s) per square centimeter
µm	= micrometer
nm	= nanometer
Ω cm	= ohm-centimeter
E	= Young's Modulus
mK	= milli Kelvin
ºC	= Degree Celsius

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

One of the major factors limiting fuel cell commercialization is the development of bipolar plates, which are one of PEMFC's key components. Several types of materials are currently used in bipolar plates, including non-porous graphite plates, metallic plates with or without coating and a number of composite plates.

The bipolar plate is one of the most important components in a PEM fuel cell. A polymer composite bipolar plate possessing high strength and high stiffness has been developed by making use of carbon fiber network in a specific form as the filler component. The bipolar plates are in weight and volume the major part of PEM fuel cell stack, and also a significant effect to the stack cost.

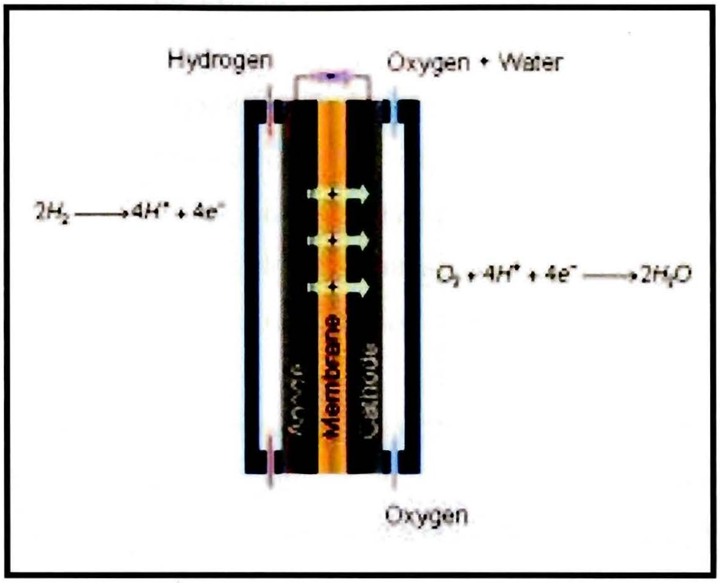

Figure 1.1: Fuel cell

So far, many different materials for bipolar plates have been investigated and an alternative solution consists in polymer composite that combine the process ability and mechanical properties of the polymeric phase and the conductivity of the carbon fillers. Both thermo-set resins and thermoplastics were considered and combined to many different carbon fillers. [1]

The interests and limitations of these formulations are presented in terms of process ability and most relevant properties. A composite material is made by combining two or more materials to give a unique combination of improved properties, such that each component retains its physical identity.

In order to improve their commercial liability, many scientific and technological efforts are being performed on fuel cell systems. On the technical point of view, bipolar plates should fulfill functional challenges besides ensuring the mechanical strength of the stack. As a result an optimal material for bipolar plate application should present an unusual balance of properties, essentially high electrical conductivity and good mechanical strength.

1.1.1 Proton exchange membrane fuel cell

Proton exchange membrane fuel cell (PEMFC), also known as polymer electrolyte membrane (PEM) fuel cells are a type of fuel cell being developed for transport applications as well as for stationary fuel cell applications and portable fuel cell applications. Their distinguishing features include lower temperature/pressure ranges (50 to 100 °C) and a special polymer electrolyte membrane.

PEMFC are electrochemical devices that convert the chemical energy of reactants (a fuel and an oxidant) directly to electrical energy in the form of low voltage direct current (DC) electricity and heat. They have been receiving significant attention due to their high power density, energy efficiency, and environmentally friendly characteristics. [2]

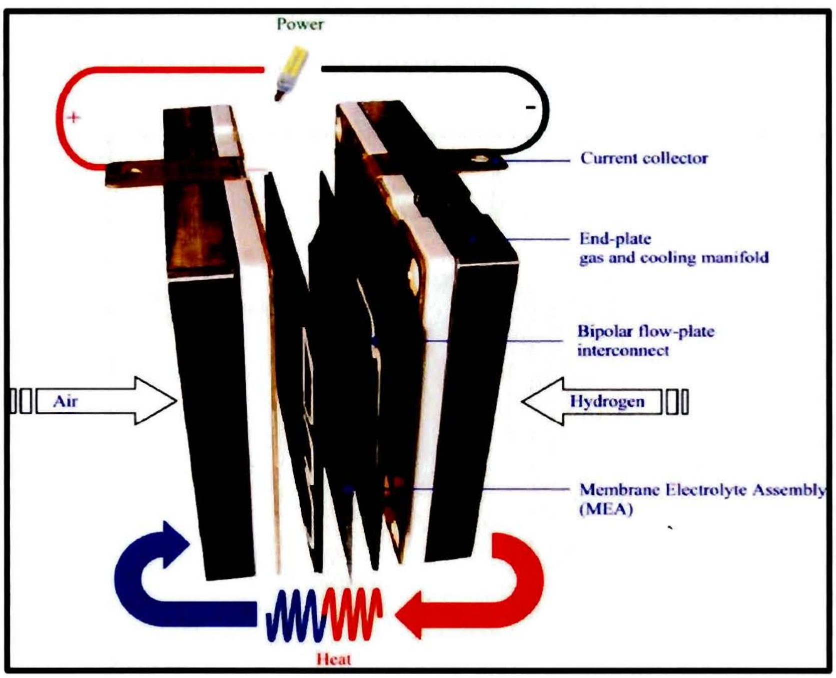

Figure 1.2: Polymer Electrolyte Membrane Fuel Cell (PEMFC) [7]

1.1.1.1 Polymer Electrolyte Membrane Fuel Cell Operation

1. Pure hydrogen constantly flows from a simple cylinder containing compressed hydrogen into the fuel cell and onto the anode it is then split into hydrogen ions and electrons.

2. The electrons cannot pass through the electrolyte therefore; they pass through the external circuit creating an electric charge.

3. The electrolyte is sandwiched between the anode and cathode, which is permeable to protons but does not conduct electrons. Hydrogen ions (protons) permeate across the electrolyte to the cathode. Electrons flow through an external circuit and provide power.

4. Oxygen is fed into the fuel cell onto the cathode (positive electrode). The cathode combines electrons, protons and oxygen to form the by product which is water. The water then leaves the cell. This is a continuous process so as hydrogen and oxygen is supplied. [3]

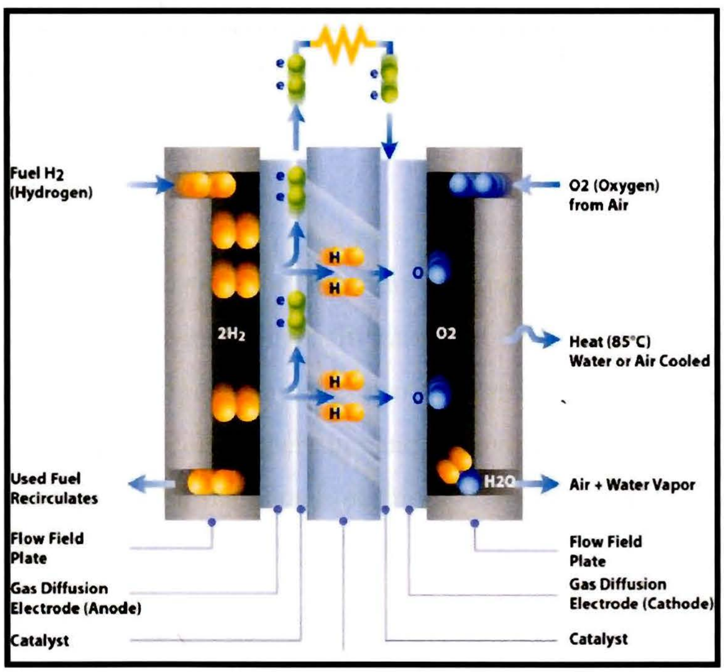

Figure 1.3: Operation of PEMFC [4]

1.1.2 Component of PEMFC

The components of PEMFC are bipolar plates, electrolyte membrane with anode and cathode(MEA) and catalyst.

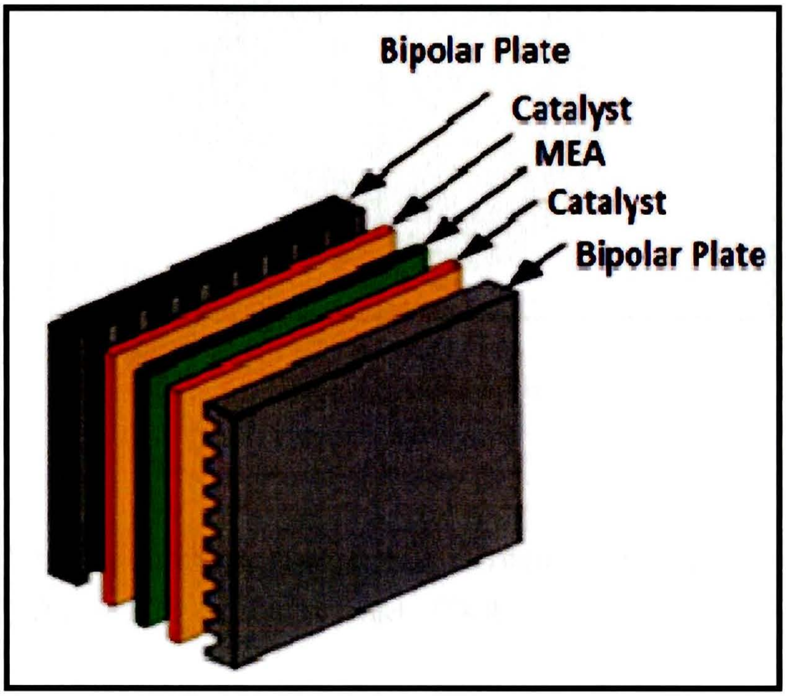

Figure 1.4: The illustration of components of PEMFC

1.1.2.1 Bipolar Plate

Bipolar plates are responsible for collecting and transporting electrons from the anode and cathode, as well as, connecting individual fuel cells in series to form a fuel cell stack of the required voltage. They are also responsible for providing thermal conduction to help regulate fuel cell temperature and removing heat from the electrodes, delivering fuel gas and air to the membrane electrode assembly (MEA), and carrying exhaust gas and product water away from the MEA.

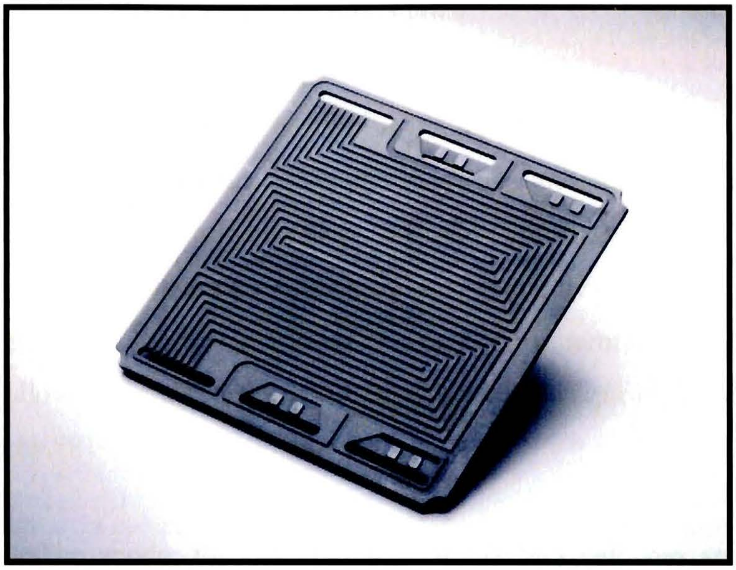

Figure 1.5: Bipolar Plate [5]

In polymer electrolyte membrane fuel cell (PEMFC) design, bipolar plate should require as follows [6]:The requirement also the target of DOE requirement for bipolar pate.

a. Good electrical conductivity (>100 S cm^(-1) bulk conductivity)
b. High Shore Hardness (>40)
c. Good bulk density (~1.85 g cm^(-3))
d. Good flexural strength (>25 MPa)
e. High tensile strength (>41 MPa)
f. Low permeability for hydrogen (<2x 〖10〗 ^(-6) cm^3)
g. High thermal conductivity (>10 W cm^(-1))
h. High chemical and corrosion resistance (<1 μA cm^(-2))
i. Low surface contact resistance
j. Mechanical stability toward compression forces
k. Low-cost material being process-able with mass production techniques
l. Low weight and volume
m. Recyclable materials.

1.1.2.2 Membrane Electrolyte Assembly (MEA)

A key component of a PEM fuel cell is the Membrane Electrolyte Assembly or MEA. The MEA consists of two electrodes, the anode and the cathode. These are porous carbon electrodes, which are each coated on one side with a low amount of platinum catalyst and separated by a proton exchange membrane (PEM). The PEM is the electrolyte in this assembly. It is a thin sheet that is only permeable for protons and water. It must allow hydrogen protons to pass through but prohibit the passage of electrons and gases. [8]

1. Anode - The anode, the negative side of the fuel cell, has several jobs. It conducts the electrons that are freed from the hydrogen molecules so they can be used in an external circuit. Channels etched into the anode disperse the hydrogen gas equally over the surface of the catalyst.

2. Cathode - The cathode, the positive side of the fuel cell, also contains channels that distribute the oxygen to the surface of the catalyst. It conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

3. Polymer electrolyte membrane - The polymer electrolyte membrane (PEM)—a specially treated material that looks something like ordinary kitchen plastic wrap—conducts only positively charged ions and blocks the electrons. The PEM is the key to the fuel cell technology; it must permit only the necessary ions to pass between the anode and cathode. Other substances passing through the electrolyte would disrupt the chemical reaction.[9]

1.1.2.3 Catalysts

The PEMFC catalysts are the reaction sites where the electrochemical reactions occur. They are usually very thinly coated onto carbon paper or cloth.The catalyst is a porous platinum coating on the anode which speeds up the reaction.

The platinum coating prevents the formation of hydrogen peroxide which is highly corrosive to the fuel cell.

In a fuel cell, hydrogen gas flows to the anode. There, with the help of the catalyst, the molecules are broken down into protons (hydrogen ions) and electrons. The positively charged protons go through the porous membrane and migrate toward the cathode. [10]

1.2 OBJECTIVE

The main objectives of this analysis are to analyze regarding composites and therefore the electrical conductivity of G, St and PP together with the impact of Graphite as a main filler and Stainless Steel as second filler. This analysis evaluated as well as the ratio of the weight percentage of the composite.

Those objectives evaluated are to assist and complete this study:

1. To study the effect of Stainless steel on the properties of G/ PP composite.
2. To determine the critical loading of St in G/PP composite for bipolar plate.