SUPERVISOR DECLARATION

I hereby declare that I have read this project report 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).

Signature : ....

Name of Supervisor : DR. MOHD ZULKEFLI BIN SELAMAT

Date : ....

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

MOHAMAD NAZIM BIN MOHD NASIR

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DECLARATION

I declare that this project report entitled "Effect of Stannum on the Properties of Gr/Sn/PP Composite of Bipolar Plate" is the result of my own work except as cited in the references

Signature	:	....
Name	:	MOHAMAD NAZIM BIN MOHD NASIR
Date	:	....

DEDICATION

Expecially for my father, Mohd Nasir Bin Abd Kadir and my mother, Kasmawati Binti Yussof

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ABSTRACT

In this research, the high performance bipolar plate were fabricated by using compression molding. In polymer electrolyte membrane fuel cell (PEMFC), bipolar plate is considered one of the most important components which takes a large portion of stack stock. It has a multi-functional in the fuel cell stack. The fuel cells are the most promising power source in the future because it can provide good energy efficiency, little pollution and little noise. In this project, the raw materials used to fabricate the high performance bipolar plate are Graphite (Gr), Stannum (Sn) and Polypropylene (PP). The Gr and Sn will be used as fillers and PP will be used as binder (Resin).The composition ratio of fillers: binder will be fixed 80%; 20%. But for main-conductive filler ratio of Gr will vary from 70%, 65% and 60%. Meanwhile, the second conductive filler, Sn will vary from 10%, 15% and 20% from the total percentages of fillers (80%). The Polypropylene (PP) will be pulveriser and sieve in order to get 500µ sizes. The fillers material will be mixed with binder material by using the ball mill machine before shaped by using the hydraulic compression molding machine with three different temperature such as 165˚C, 170˚C and 175˚C. The effect of Sn loading and temperatures on the electrical conductivity and mechanical properties of GR/Sn/PP composite have been evaluated. The result shows that density and hardness have meet DoE standard and just electrical property and flexure strength did not meet the DoE, thus due to agglomeration complication and PP does not distribute well in bipolar plate. The maximum value of all testing result are electrical conductivity is 49.65 S/cm, flexural strength is 15.46 MPa, bulk density is 1.960 g/cm^3 and shore hardness is 61.

ABSTRAK

Dalam kajian ini, prestasi tinggi plat dwikutub telah direka dengan menggunakan acuan mampatan. Dalam polimer sel bahan api membran elektrolit (PEMFC), plat dwikutub adalah merupakan sebagai salah satu komponen yang paling penting yang menyumbang sebahagian besar berat tindanan. Ia mempunyai pelbagai fungsi dalam tindanan sel bahan api. Sel bahan api adalah sumber kuasa yang paling utama di masa akan datang kerana ia boleh memberikan kecekapan tenaga yang baik, pencemaran sedikit dan bunyi sedikit. Dalam projek ini, bahan-bahan mentah yang digunakan untuk fabrikasi plat dwikutub berprestasi tinggi adalah grafit (Gr), Stannum (Sn) dan Polypropylene (PP). Gr dan Sn akan digunakan sebagai pengisi dan PP akan digunakan sebagai pengikat (Resin). Nisbah komposisi pengisi: pengikat ditetapkan pada 80%; 20%. Tetapi untuk nisbah pengisi konduktif utama Gr adalah 70%, 65% dan 60% .Sementara itu, pengisi konduktif kedua Sn adalah 10%, 15% dan 20% daripada jumlah peratusan total pengisi (80%). Polypropylene (PP) dikisar dan ayak untuk mendapatkan 500 mikron saiz. Bahan pengisi dicampurkan dengan bahan pengikat dengan menggunakan mesin kempa bola sebelum dibentuk dengan menggunakan mesin pengacuan mampatan hidraulik dengan tiga suhu yang berbeza iaitu 165˚C, 170C dan 175˚C. Kesan bebanan Sn dan suhu terhadap kekonduksian elektrik dan sifat mekanikal Gr / Sn / PP komposit telah dinilai. Hasil kajian menunjukkan bahawa sifat ketumpatan dan kekerasan telah memenuhi piawaian DoE dan hanya elektrik dan kekuatan lenturan tidak memenuhi DoE, itu disebabkan oleh penumpuan komplikasi dan Sn tidak tertabur dengan baik dalam plat dwikutub. Nilai maksimum samba hasil ujian adalah kekonduksian elektrik adalah 49.65 S/cm, kekuatan lenturan adalah 15.46 Mpa, ketumpatan pukal adalah 1,960 g/cm^3 dan pantai kekerasan adalah 61.

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PEMFC	Polymer Electron Membrane Fuel Cell
CPCs	Conductive Polymer Composites
US-DoE	United State Department of Energy
Gr	Graphite
Sn	Stannum
PP	Polypropylene
ICP	Impact Copolymer
HPP	Homo-polymer Polyproplyene
ASTM	American Society for Testing and Materials
S/cm	Siemen per Centimeter
Mpa	Mega Pascal
g/ cm^3	Gram per $centimeter^3$
µm	Micron Meter
µA	Micron Ampere

CHAPTER 1

INTRODUCTION

1.1 FUEL CELL

A fuel cell is a device that uses an electrochemical reaction to directly convert the chemical energy of a fuel into useable electricity. It converts hydrogen and oxygen into water and this process also creates the electricity. Some other hydrocarbon such as natural gas and alcohol are also used as the fuel for fuel cell. In the fuel cell, the hydrogen gas is reacted with the oxidizing agent or oxygen to form water. It requires a constant sources of fuel and oxygen to produce the electricity continually as long as the sources are supplied constantly. Beside that,producing energy with water is an attractive concept behind fuel cell. The function is by combining hydrogen with oxygen as the simple reaction (Elizabeth and Condliffe, 2002).

The fuel cell are also known as the promising power source in future for residential, mobile and automative application. It can provide good energy efficiency over 40%, little poluttion and little noise (Lee et al, 2007). Fuel cells are extremely attractive from an environmental standpoint because electrical energy is generated without combusting fuel. Fuel cells are known as great potential to be low emission power generation sources in the future due to its attractive characteristics such as high energy conversion efficiency (Antunes et al, 2011) very low chemical and acoustical pollution (Kuan et al, 2004).

Fuel cells works much like a battery, except it did not require electrical recharging. A battery stores all of its chemicals inside and coverts the chemicals into electricity. Once those chemicals run out, the battery dies. On the other had, fuel cell gets the chemicals it utilizes from the outside in this way, it did not run out. Fuel cells can generate power almost indefinitely, as long as they have fuel to use. In the future, fuel cells are known as the most potential power sources for residential, mobile and automotive applications. Fuel cells have the potential to replace the internal combustion engine in vehicles and provide power in stationary and portable power applications because they are energy efficient, clean, and fuel flexible (Muller et al, 2006).

By the same principle of producing hydrogen with oxygen to form water, Table 1.1 below has shown details each five types different of fuel cells have developed including typical size, efficiency, advantages and disadvantages.

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEM)	Perfluoro sulfonic acid	50-100°C 122-212°F typically 80°C	< 1kW-100kW	60% transportation 35% stationary	• Backup power • Portable power • Distributed generation • Transporation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up	• Expensive catalysts • Sensitive to fuel impurities • Low temperature waste heat
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90-100°C 194-212°F	10-100 kW	60%	• Military • Space	• Cathode reaction faster in alkaline electrolyte, leads to high performance • Low cost components	• Sensitive to CO_2 in fuel and air • Electrolyte management
Phosphoric Acid (PAFC)	Phosphoric acid soaked in a matrix	150-200°C 302-392°F	400 kW 100 kW module	40%	• Distributed generation	• Higher temperature enables CHP • Increased tolerance to fuel impurities	• Pt catalyst • Long start up time • Low current and power
Molten Carbonate (MCFC)	Solution of lithium, sodium, and/or potassium carbonates, soaked in a matrix	600-700°C 1112-1292°F	300 kW-3 MW 300 kW module	45-50%	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP	• High temperature corrosion and breakdown of cell components • Long start up time • Low power density
Solid Oxide (SOFC)	Yttria stabilized zirconia	700-1000°C 1202-1832°F	1kW-2 MW	60%	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte • Suitable for CHP & CHHP • Hybrid/GT cycle	• High temperature corrosion and breakdown of cell components • High temperature operation requires long start up time and limits

Table 1.1: Details on each type of Fuel Cell (Olsen, 2013)

1.1.1 Polymer Electrolyte Membrane Fuel Cell

Polymer Electrolyte Membrane Fuel Cells (PEMFC) are power generating devices that use an electrochemical reaction to change the energy from hydrogen fuel into usable power. It also known as fuel cell where electrolyte is made of an organic polymer that has the characteristic of a good proton carrier when in presence of a water solution (Costal et al, 2006).

The PEMFC are considered as for commercialization for portable and transportation applications because of their high energy conversion efficiency, low temperature, high power density and low pollutant emission. Besides that, cost and durability of PEMFCs are the two main challenges that must to be addressed to enable their commercialization (Maiyalagan and Pasupathi, 2010).

The PEMFC can convert the chemical energy from the hydrogen (Fuel) and oxygen (Oxidant) direct to electrical energy. The by-products of this reaction are only water and heat. The Figure 1.1 below show that the basic diagram in PEMFC.

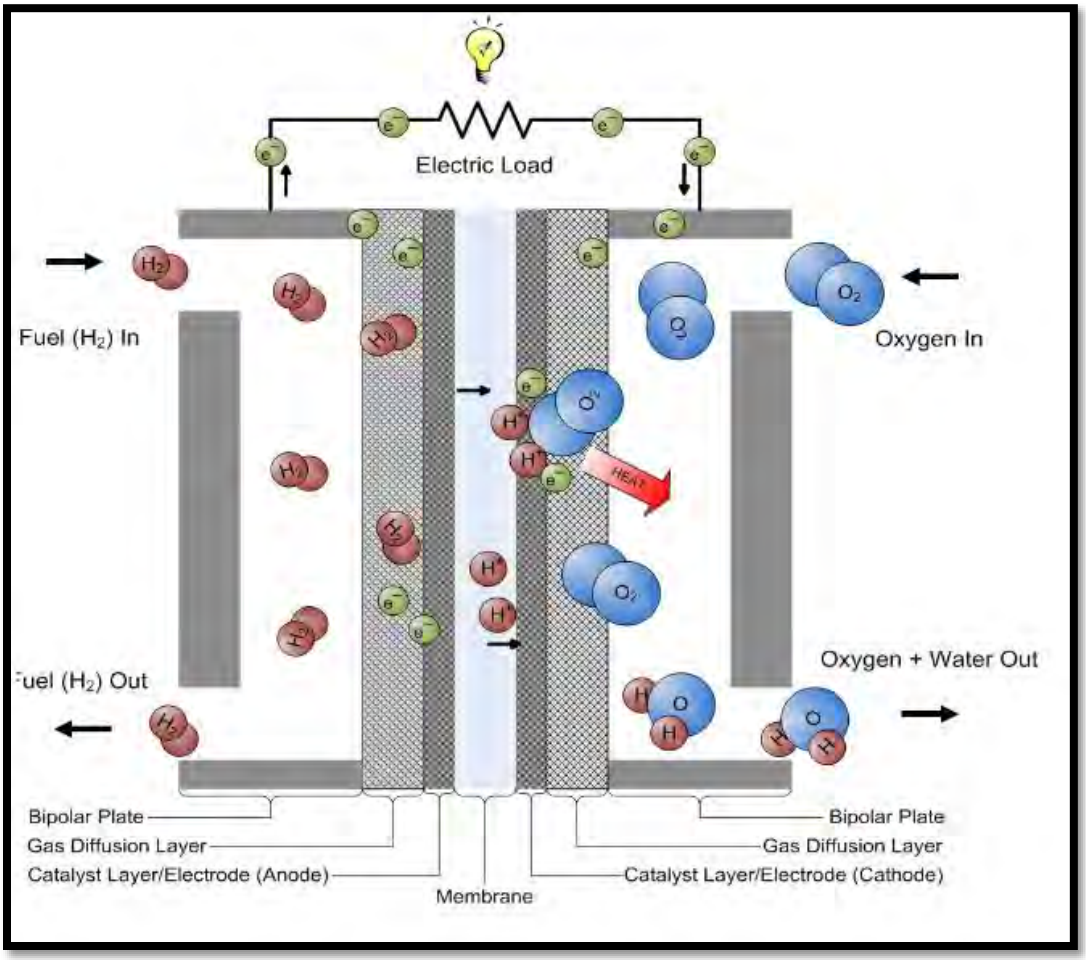

Figure 1.1: Basic Diagram of a PEMFC (Yan et al, 2015)

1.1.2 Components of Fuel Cell

The major components of the PEMFC are the Membrane Electrolyte Assembly (MEA), gasket, gas diffusion layer, bipolar plate, current collectors and endplates. The Figures 1.2 below shows the major components in PEMFC. Membrane Electrodes Assembly (MEA), bipolar plate, current collector and end plate are 4 main components of PEMFC.

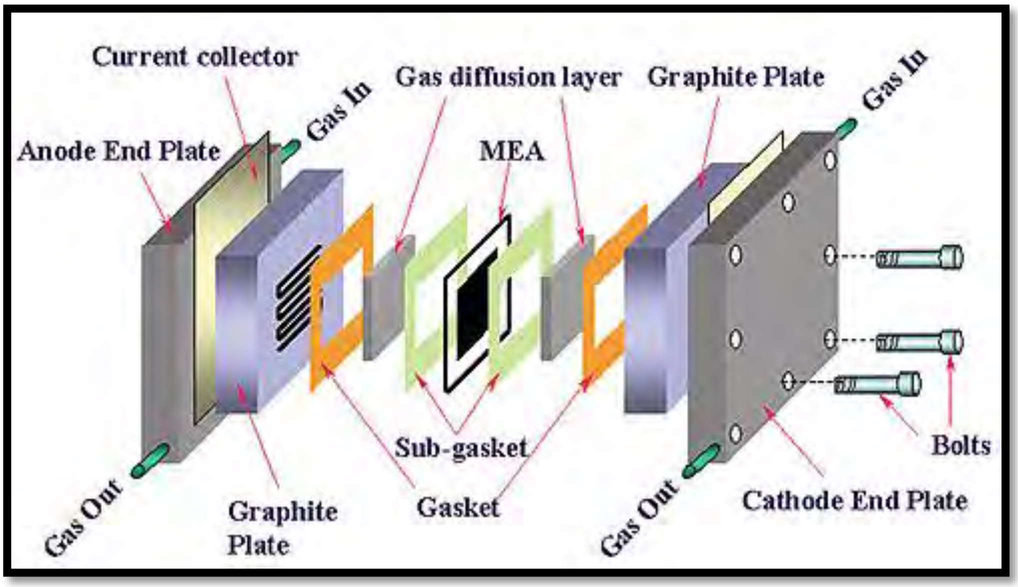

Figure 1.2: Major Components in the PEMFC

1.2 Problem Statement

Generally, in current fabrication of bipolar plate carbon based Gr, CB and CF, Gr and metal based Ferum are used as conductive fillers. Meanwhile PP is used as the binder. The main problem of metal is high tendency to corrosion, for pure graphite are too brittle and low in electrical conductivity, PP is non-conductive material and have a low strength. But through composite approach, the high performance bipolar plate can be produce. The composite approach is the use more than one conductive fillers to produce bipolar plate. But in fabrication of bipolar plate, not much research has been done to use the carbon based conductive fillers combined with metal based conductive fillers.

In this research, powder of PP is used as the binder and Gr and Sn as conductive fillers. Through composite approach, carbon based material Gr and Sn which this metal will be combine with PP to produce composite of Gr/Sn/PP. So the uses of PP can improved the brittle of graphite. However the combination of Gr/Sn/PP can increase the electrical of conductivity. The size of PP will be used is 500µm. To determine the effected of Sn loading, several related test such as conductivity, flexure test, density test, hardness and microstructure analysis will be performed.

1.3 Objective

The main objectives of this research are to study the effect of the Sn on the properties of Gr/Sn/PP composite for bipolar plates to be used in fuel cell. In this research is use as a main filler and powder of PP is used as the binder. The main objectives of the research are:

1. Study the effect of Sn loading on the properties of Gr/Sn/PP composite.
2. Determine the suitable temperature for Gr/Sn/PP composite through hot compression molding.

1.4 Scope of Project

This research will study the effect of Sn on the electrical and mechanical properties of Gr/Sn/PP composite. The ratio of filler (Gr/Sn) and binder (PP) is fixed at 80:20.The adding of small amount of SS in to Gr/Sn/PP composite thus will give synergy effect on electrical conductivity and mechanical properties. The small amount of Sn which is 10% is up to 20% (from the total weight of filler 80%) will be added into Gr/Sn/PP composite. Before the fabrication process using the hot press with the temperature up to 175˚C, the mixture of Gr and Sn will be mixed used ball mill. In order to determine the effects of Sn, several size of PP powder (500µm) will be used in Gr/Sn/PP composite, the test such as electrical conductivity, flexure test, density test, hardness and microstructure analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 CONDUCTIVE POLYMER COMPOSITE

Conductive polymer composites (CPC) are formed by combination of conventional polymer with conductive polymers or filler allow creating new polymeric materials with unique elctrical properties. Carbon black, graphite or other conductive filler are commonly used as a components of conductive polymer composites. A proper balance between electrical conductivity, mechanical properties and processing charasteristic is an important requirement for a design of electroconductive thermoplastic composites (Omastova and Chodaka, 1999).

Futhermore, certain polymer are naturally conductive because they have conjugated chain structure and polymer like polyethlyne and polyproplene are not conductive because they do not have conjugated structure. They can become conductive by adding the conductive fillers like carbon black, graphite, metal and other conductive fillers. The factor that affecting the properties of a composites material are type of the fillers, filler size, filler dispersion, orientation of fillers in matrix, polymer matrix and some other factors. The most important charasteristic to improve the properties of the composites materials is the interaction of fillers and polymer chain (Jianhua and Huang, 2005). The interaction takes place by attraction between the polymer chainand filler or chemical bonding between the polymers matrix and filler material. Chemical bonding between polymers matrix and filler materials can give the charge carriers move along polymer chain (Ahmad and Narissa, 2012).

2.1.1 Percolation Theory

The percolation theory explain about the composite electrical conductivity near the percolation rhresold value or critical volume Flory (1941) and Stockmayer (1943) have produced the percolation process to explain how small branching molecules react to form very big macromolecules (Stauffer, 1985). In an observation of electrical conduction in a polymer matrix, electron are able to move through conductive filler particles. When the fillere particles is in contact with one another for the electron to travel through. A continuous path can form through the polymer matrix and this path is known as conductive network. The materials with conductive network can turns to conductinbg material as shown in Figure 2.1

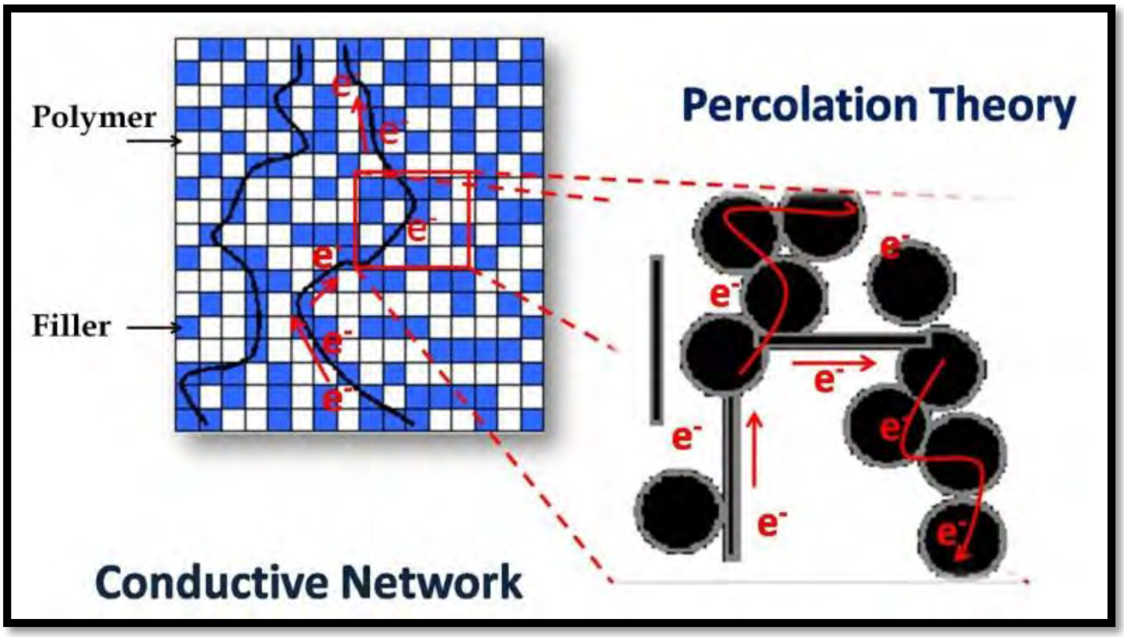

Figure 2.1 :Schematic of Percolation Pathway (Yeetsorn, 2010)

For the increment of conductive filler loading, as shown in Figure 2.2 the graph can divided into three main region to describe the relationshipto the conductivity of conductive filled polymer composite. At region A which is a low filler loading, there are no path occurs for electron to transport and the electrical conductivity value is equal to zero. The composites is still like a pure polymer matrix. At a certain critical loading is known as the percolation threshold. Sufficient filler has been put so that the continuous conductive network is formed through the composite. Next to percolation threshold is a region with very slight increase in filler amount will produce a large increase in conductivity,as displayed by region B. After the region of accelerates increase,the conductivity decelerates its increase, and method that