EFFECT OF CARBON NANOTUBE ON THE PROPERTIES OF GRAPHITE - CARBON BLACK-EPOXY COMPOSITE FOR BIPOLAR PLATE

AZNY BINTI MOHD BASAHAHRUDDIN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SUPERVISOR DECLARATION

"I hereby 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)"

Signature : .....
Supervisor : .....
Date : .....

EFFECT OF CARBON NANOTUBE ON THE PROPERTIES OF GRAPHITE - CARBON BLACK-EPOXY COMPOSITE FOR BIPOLAR PLATE

AZNY BINTI MOHD BASAHAHRUDDIN

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

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

JUNE 2017

DECLARATION

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

Signature :
Author :
Date :

ACKNOWLEDGEMENT

First and foremost, I have to thank my research supervisors Dr, Mohd Zulkefli bin Selamat. Without his assistance and dedicated involvement in every step throughout the process, this research and report would have never been accomplished. I would like to thank you very much for your support, encouragement and guidance.

I would like t say thank you to Universiti Teknikal Malaysia Melaka and Faculty of Mechanical Engineering for providing me an opportunity to do my research with given a lot f information and facilities throughout the run of my Final Year Project (FYP)

I also would like to say thank you to my friends for listening and tolerance me over the past three years. I cannot begin tp express my gratitude and appreciation for their friendship.

Last but not least, the most important , none of this could have happened without my family. To my family, it would be an understatement to say that we have experience some ups and downs in the past three years. Every time i was down and stress with it, you all the one aways support me. This FYP stands as a testament to your unconditional love and encourages. Thank you very much to all of them for their manual support and helps. Thank you.

ABSTRACT

The conductive polymer composite(CPCs) bipolar plate had been the target to replace the pure-graphite. This is due to the low manufacturing cost and light of total mass of bipolar plate in PEMFCs. The aim of this research is to study the effect of CNTs on the properties of Gr/CB/EP composite. The second aim of this research is to determine the critical loading of CNTs in Gr/CB/EP composite. The ratio of fillers (Gr/CNT) and binder (EP) is fixed at 75:25. The amount of CB also will be fixed 25% and by adding the small amount of CNTs in to Gr/CNT/EP composite thus will gives synergy effects on electrical conductivity and mechanical properties. The small amount of CNTs which is 0, 5, 10 and 15 wt.% (from the total weight of fillers 75%) will be added into Gr/CB/EP composite. Before the fabrication process using the hot press, the filler of Gr/CB/CNT will be mixed used ball mill. In order the determines the effect of CNTs content in Gr/CNT/EP composite, the test such as electrical conductivity, flexure test, density test hardness and microstructure analysis has been carried out. The best weight of CNTs contents are at 10wt% in Gr/CB/EP.

ABSTRAK

Polimer konduksian plat dwikutub komposit (CPCs) telah menjadi sasaran menggantikan grafit tulen. Ini adalah disebabkan kos perkilangan rendah.Tujuan penyelidikan ini adalah untuk belajar kesan CNTs pada Gr/CB/EP.Tujuan kedua penyelidikan ini adalah untuk menentukan pemuatan kritikal CNTs dalam Gr/CB/EP. Nisbah pengisi (Gr/CNT) dan pengikat (EP) ditetapkan pada 75:25. Jumlah CB juga akan ditetapkan 25% dan dengan menambahkan sedikit CNTs dalam kepada Gr/CNT/EP maka akan memberi kesan-kesan sinergi di kekonduksian elektrik dan sifat mekanik. Sedikit CNTs yang merupakan 0, 5, 10 dan 15 berat.% (dari jumlah berat pengisi 75%) akan ditambah ke dalam Gr/CB/EP. Sebelum proses pembuatan menggunakan penekan panas, pengisi Gr / CB / CNT akan bercampur dengan mengunakan pengisar bola.Dalam usaha menentukan kesan CNTs dalam Gr / CNT / rencam EP, ujian seperti kekonduksian elektrik, ujian kekuatan lenturan, kekerasan ujian kepadatan dan analisis mikrostruktur telah dilaksanakan. Berat terbaik kandungan CNTs berada di 10wt% dalam Gr / CB / EP.

CONTENT

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBEREVATIONS

CNTs	Carbon Nanotubes
CB	Carbon Black
Gr	Graphite
EP	Epoxy
PEMFCs	Polymer Electrolyte Membrane Fuel Cell
DC	Direct Current
DOE	Department of Environment
CPC	Conductive Polymer Compositions

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Fuel cell in today plays an important role for the progress of a country. Therefore, to reduce energy consumption a lot, have focused on environmental factors. Therefore, Proton Exchanges Membrane Fuel Cells (PEMFCs) are introduced. So, at low temperatures PEMFCs will converts hydrogen and oxygen into electrical energy. In terms of transportation, PEMFC fuel cell is being developed. It is a fuel cell that does not move and the portable fuel cell. PEMFCs is also known as Polymer Electrolyte Membrane (PEM).

Bipolar plate (BPs) has become a very hot issue of research and critical. In research carried out, BPs must have a specifications, application, electrical and also thermal conductivity. The application must present physical properties and chemistry. Therefore, combination of reinforce of BPs material has been used to archived good electrical conductivity. The Department of Environment (DOE) has set the characteristics of the ideal Bipolar Plates. The fabrication of BPs should be satisfied. The properties requirement shown in Table 1.1.

Table 1.1 Properties specification by DOE (source : Yeetsorn et al, 2012)

Properties	**Value**
Electrical conductivity	>100
Thermal conductivity	>10
Flexural strength	>25[MPa]
Shore Hardness	>50
Bulk Density	<5[g/c]

1.2 PROBLEM STATEMENT

Nowadays, Polymer Electrolyte Membrane Fuel Cell (PEMFC) get more researches. Due to they want to change of pure graphite or metal based bipolar plates. This is because it more attractive of high power density, low operating temperature and converting fuel to water. Based on a study did by Selamat M.Z (2013) is the most commonly used of bipolar plate materials are graphite materials. Due to the graphite have excellent corrosion resistance, high electrical conductivity, and a lower density than the other materials. But, the disadvantages graphite materials is very high cost of machining channels into the surface and their vulnerability will cause the fuel cell stack becomes heavy and voluminous. Conducting Polymer Composite (CPC) is fabricate from the mixed of conductive fillers such as Gr/CB/CNT had been incorporated in EP as matrix for fabrication of electrical conductive polymer composite plate. The advantages of CPC are easy of shaping, low density, and wide range of electrical conductivities as well as corrosion resistance.

1.3 OBJECTIVE

The main objective of this research is:

i. To study the effect of Carbon Nanotubes (CNT) on the properties of Graphite(Gr), Carbon Black(CB), and Epoxy (EP) composite.
ii. To determine the critical loading of CNT in Gr, CB, and EP composite.

1.4 SCOPE OF PROJECT

This research will study the effect of carbon Nanotubes (CNT) loading on the electrical and mechanical properties of Gr, CNT, and EP composite. The ratio of fillers (Gr/CNT) and binder (EP) is fixed at 75:25. The amount of CB also will be fixed 25% and by adding the small amount of CNTs in to Gr/CNT/EP composite thus will gives synergy effects on electrical conductivity and mechanical properties, The small amount of CNTs which is 0, 5, 10 and 15 wt.% (from the total weight of fillers 75%) will be added into Gr/CB/EP composite. Before the fabrication process using the hot press, the filler of Gr/CB/CNT will be mixed used ball mill. In order the determines the effect of CNTs content in Gr/CNT/EP composite, the test such as electrical conductivity, flexure test, density test hardness and microstructure analysis will be performed.

CHAPTER 2

LITERATURE REVIEW

2.1 FUEL CELL

Fuel cells is a device of electrochemically which changes the chemical from energy of gaseous or liquid reactants into direct current (DC) electricity. In the simplest case of fuel cell, it was operating with hydrogen (fuel) and oxygen (air) as reacting gases. Figure 2.1 shows the basic of operation fuel cell. A proton or oxide ion was current equivalent to the electrolyte and parts of the homogeneous electrodes structure.

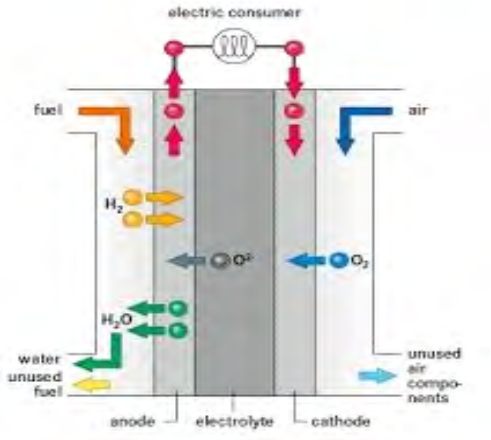

Figure 2.1 : Basic Fuel Cell
(fuel cell & hydrogen energy Association 2015)

All types of fuel cells require a fuel that reacts with oxygen and in the process releases the chemical energy contained in the fuel. However, the energy is not discharged in the form of heat but as electrical energy.

The electrons released in this process are transported by an external electric circuit to the load, thus providing electric energy. Compared to conventional power plants in which heat from the combustion of fuels is converted into electricity mechanically (by means of generators), in fuel cells, a substantial part of the energy losses involved in the power plant process is avoided because there is no combustion step.

Although in principle, fuel cells have a very simple structure, it is a challenge to identify materials that have the required properties, and are able to convert fuel and oxygen into usable electricity. Even when suitable materials have been found, another difficulty consists of giving them the right shape and making sure that the device built from these materials are robust and have a long lifetime.

2.2 POLYMER ELECTROLYTE MEMBRANCE FUEL CELL (PEMFCs)

The purpose of Proton-exchange membrane fuel cells (PEMFCs) are to changes the energy for suitable applications with difference requirements. The material combinations of PEMFCs that used also must difference. But need to get the properties of bipolar plates the properties for bipolar plates are as follows:

- Have electrical conductivity that >100 S cm bulk conductivity.
- The thermal conductivity must >20Wcm
- High chemical and corrosion resistance.
- Mechanical stability toward compression forces.
- The low permeability for hydrogen.
- Mass production techniques must have low-cost material being process able.
- Low volume and weight.

2.3 MAIN COMPONENT OF FUEL CELL

Figure 2.2 shows the structure diagram of PEMFCs. There are three main components of PEMFCs which are Membrane Electrode Assembly (MEA) Bipolar plate (BPs) and End plate. The MEA is the heart component of PEMFCs and work currently being done to find cheaper and thinner membranes whilst maintaining durability.

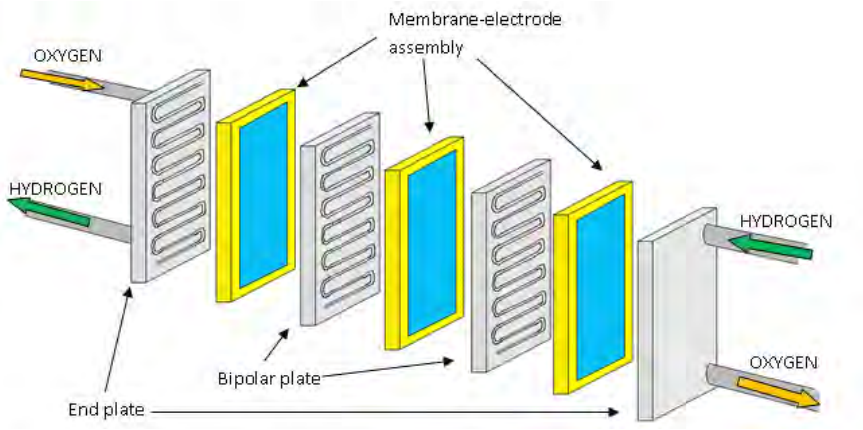

Figure 2. : Structure Diagram PEMFCs.

(Source : Yilser Devri,2012)

2.4 CONDUCTIVE POLYMER COMPOSITES(CPCs)

Conductive polymer composites (CPC) and coated-metallic bipolar plates are widely studied as alternative materials to conventional carbon-carbon plates. Polymer based BPs use thermoplastics, thermosets or elastomers as matrix material and to ensure high electrical conductivities. That contain carbon-based conductive fillers such as Gr, CB and CNTs. These composites are produced via melt mixing and injection or compression moulding. They possess good corrosive behaviour due to inert structure of polymer.

Moulding techniques shorten the production cycle-time, carry out porous-free bipolar plates and facilitate flow field design. As polymer itself behaves like insulating material, to convert it into conductive phase requires attentive introduction of conductive fillers into the matrix. The higher the concentration of filler, the higher the probabilities have to a porous structure or inferior mechanical properties. The dispersion state of filler is another important issue to take care. Especially high surface area fillers such as carbon nanotubes tend to create agglomerates due to inter-particle Van der Waals forces. To benefit from their properties, those agglomerates should be well disentangled and homogeneous filler dispersion should be maintained

2.5 MATERIALS

The materials used to produce CPCs samples are Gr, CB and CNTs powder. The binder in this research is Epoxy. Table 2.1 shows the main materials properties

Table 2.1. : Material Properties of Gr/CB/CNTs/EP

(Source : Selamat,et al.2013)

Material	Gr	CB	CNTs	EP
Grade	3243	5303	NC 7000	105/206
Density	1.74 g/cm^3	1.7-1.9 g/cm^3	1.0 g/cm^3	1.15 g/cm^3
Thermal stability	3500-4000 ^{0}C	3000 ^{0}C	>700 ^{0}C	180-220 ^{0}C
Size	$\leq 60 \mu m$	$\leq 5 \mu m$	9.5 nm (diameter) 1.5 μm (length)	-
Resistivity	$0.036 \Omega cm$	$0.314 \Omega cm$	5-5 $\mu \Omega cm$	$1(1014 \Omega m)$

2.5.1 Fillers

In order to achieve a good electrical conductivity of the composite, the combination of multi-fillers have been used as bipolar plate. The reinforcement fillers used commonly used including Gr, CB, and CNTs. Those fillers are which have been incorporated into the composite.

2.5.1.1 Carbon Black (CB)

Black carbon is carbon that is controlled in the production process and forms aggregates also vary in size, porosity and surface chemistry. Carbon Black typically contains more than 95 % pure carbon with minimal quantities of oxygen, hydrogen and nitrogen. In the manufacturing process that uses carbon black, carbon black particles will form different shapes. The size of the carbon black is 10nm to 500nm. The combine into a chain-like aggregates, which determines the structure of individual carbon black grades.

While in the polymer industry, to obtain black fine particles of carbon black used. The main function of carbon black is the ability to absorb UV light in turn convert it to produced heat. Thus, the manufacture of polymers such as polypropylene and polyethylene are becoming more resistant and can prevent contamination by UV radiation from sunlight. In addition, carbon black is used as the insulating polymer in the production of wire and cable. It also can improve the insulating properties of polystyrene, which is widely used in construction

Figure 2.3: Carbon Black

2.5.1.2 Graphite (Gr)

Graphite is the most crystalline form of carbon, apart from diamond and fullerenes. Figure below shown the graphite. It exhibits the properties both metal such as thermal and electrical conductivity and of a non-metal such as inertness, high thermal resistance and lubricity. Based on the research of Saparuddin,(2012) it stated that optimization of the property is only possible if the percolation threshold of the conductive filler in the polymer matrix is known. Polymer based composites BPs achieve their electrical performance by the incorporation of specific loading of conductive inorganic.

Figure 2.4: Graphite

2.5.1.3 Carbon Nanotube (CNTs)

Nanoscopic particles of carbon nanotubes are tubular structures formed by carbon atoms. Diameter size between 1 and 50 nm for the normal duration of one micrometre up to a few centimetres. Therefore, the ratio of CNTs can be very large. Advantages of CNTs are available in commercial form multiwall or in the laboratory as a wall. Since their discovery, the physical characteristics unique has led to enormous interest. With a very large elastic modulus, carbon nanotubes known as a reinforcing agent effectively. Depending on their molecular structure, carbon nanotubes with small diameter show either semi-conducting or metallic behaviour.

Figure 2.5: Carbon Nanotube (CNTs)