Faculty of Mechanical Engineering

HIGH ELECTRICAL CONDUCTIVITY BIPOLAR PLATE USING STANNUM/GRAPHITE POLYMER COMPOSITE

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DECLARATION

I hereby declare that this thesis entitled "High Electrical Conductivity Bipolar Plate Using Stannum/Graphite Polymer Composite " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
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APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature	:	....
Supervisor name	:	ASSOC. PROF. DR. MOHD ZULKEFLI BIN SELAMAT
Date	:	....

DEDICATION

I dedicate this dissertation to my husband, Hamzaitul Akmarizal bin Hamdan. My gratitude for your patience, encouragement and understanding. He is always there to cheer me up when I was discouraged, wiped my tears away when I faced difficulties.

To my beloved parents, Masron b. Ahmad Dasuki and Habsah bt. Surip, my deepest gratitude for instilling the importance of higher education in me. Their love has encourage me to build a happy and successful life in the world and also in Paradise. InsyaAllah!

ABSTRACT

Nowadays, transportation is one of the promising sector for Proton Polymer Membrane Fuel Cell (PEMFC) due to the possibility of zero pollution and environment friendly vehicles and also the future expect of fossil fuels depletion . The fabrication methods of this composite and composition ratios have significant effects on its electrical and mechanical properties. This research was focused on to Graphite (G) and Stannum (Sn) as conductive fillers and Polypropylene (PP) polymer as binder. Firstly, all materials will be dry mixed using a ball mill machine with several ratios of composition. The shape of this composite was mould with the dimensions of 140 × 60 × 3 mm through the compression machine to form a bipolar plate. There were two types of composition that had been fabricated which were G/Sn and G/Sn/PP composites. Meanwhile, for G/Sn composites, two methods were applied which were sintering and compression moulding methods. For sintering method, the weight percentage of the secondary filler (Sn) is increased from 20 wt.% to 40 wt.% of the total weight percentage of fillers. Meanwhile, for G/Sn/PP, the ratio of conductive fillers and binder has been fixed at 80:20 and the ratio of conductive fillers between first and secondary filler has been varied, for G (60 to 70 wt.%) and Sn (10 to 20 wt.%). Two different types of PP polymer in powder form were used which were Low Density Polypropylene (LD-PP) and High Density Polypropylene (HD-PP). The effect of different filler material loadings on G/PP and G/Sn/PP composites properties such as electrical conductivity, bulk density, hardness and gas permeability were tested, observed and confirmed that they are able to meet the United State Department of Energy (U.S. DOE) target properties as PEMFC bipolar plate. Results showed G/Sn produced using hot compression moulded with Sn loading of 20 wt.% of Sn loading obtained the highest electrical conductivity of 889.64 S/cm. Although the usage of the hot compression moulding method increased the value of bulk density, all results still met the U.S. DOE target which is it must be lower than 1.9 g/cm^3. Other than that, hardness value for compression moulding method showed improvement compared to the sintering process method. Even though G/Sn composites for compression moulding method perform better results compared to sintered method, these composites did not exhibit good mechanical properties and showed the brittleness characteristic. These composites were also brittle. In order to overcome this weakness, PP polymer was added in G/Sn composites and the effects of PP types, Sn loading and hot compression moulding temperatures in G/Sn/PP (LD-PP and HD-PP) composites on electrical and mechanical properties were determined. Based on the results obtained, G/Sn/HD-PP composites have shown better electrical and mechanical properties as compared to G/Sn/LD-PP composites. Meanwhile, for moulding temperature for LD-PP and HD-PP were 170°C and 175°C respectively. Lastly, the optimum weight ratio of G/Sn/PP (LD-PP and HD-PP) composites was 15 wt.% of Sn loading due to high electrical conductivity, good bulk density and shore hardness value.

ABSTRAK

Pada masa kini, pengangkutan merupakan salah satu sektor yang menjanjikan peluang yang baik untuk Sistem Polimer Elektrolit Membran Sel Fuel (PEMFC) disebabkan oleh penghasilan kenderaan mesra alam sekitar dan sifar pencemaran serta pengurangan bahan api fosil pada masa hadapan. Kaedah fabrikasi, nisbah dan komposisi komposit mempunyai kesan yang besar ke atas sifat-sifat elektrik dan mekanikal. Kajian ini, tumpuan diberikan kepada Grafit (G) dan Stanum (Sn) sebagai pengisi konduktif dan polimer Polipropelena (PP) sebagai pengikat. Pertama, semua bahan-bahan akan dicampurkan menggunakan mesin pengisar bebola dengan beberapa nisbah komposisi. Komposit ini telah dibentukkan menggunakan acuan dengan dimensi 140 × 60 × 3 mm melalui mesin mampatan untuk membentuk plat dwikutub. Terdapat dua jenis komposit yang telah direka iaitu komposit G / Sn dan komposit G / Sn / PP. Bagi komposit G / Sn, dua kaedah telah digunakan iaitu kaedah pensinteran dan kaedah pengacuan mampatan. Untuk kaedah pensinteran, peratusan berat untuk pengisi kedua (Sn) dinaikkan daripada 20 wt.% sehingga 40 wt.% daripada jumlah peratusan berat pengisi. Sementara itu, bagi G/Sn/PP, nisbah pengisi konduktif dan pengikat telah ditetapkan 80:20 dan nisbah pengisi konduktif antara pengisi pertama dan kedua adalah berbeza-beza, G (60 sehingga 70 wt.%) dan Sn (10 sehingga 20 wt.%). Dua jenis polimer PP dalam bentuk serbuk telah digunakan iaitu Polipropelena Ketumpatan Rendah (LD-PP) dan Polipropelena Ketumpatan Tinggi (HD-PP). Kesan daripada perbezaan nisbah bahan pengisi di G/PP dan G/Sn/PP komposit seperti sifat kekonduksian elektrik, kekuatan lenturan, ketumpatan pukal, kekerasan dan kebolehtelapan gas telah diuji, dipatuhi dan mengesahkan mereka dapat memenuhi sasaran Jabatan Tenaga Amerika (U.S. DOE) sebagai plat dwikutub PEMFC. Keputusan menunjukkan komposit G/Sn mempunyai kekonduksian elektrik untuk kaedah acuan mampatan, komposit yang bernisbah Sn 20 wt.% menunjukkan kekonduksian elektrik yang tertinggi dengan 889.64 S / cm. Walaupun dengan menggunakan kaedah pengacuan mampatan telah meningkat nilai ketumpatan pukal, semua keputusan masih memenuhi sasaran U.S. DOE iaitu kurang daripada 1.9 g / cm^3. Selain daripada itu, nilai kekerasan "shore" untuk kaedah pengacuan mampatan menunjukkan peningkatan berbanding kaedah proses pensinteran. Walaupun komposit G/ Sn untuk kaedah pengacuan mampatan menunjukkan keputusan yang lebih baik berbanding kaedah persinteran, komposit ini tidak mempamerkan sifat mekanikal yang baik seperti kekuatan dan ia juga agak rapuh. Untuk mengatasi kelemahan ini, polimer PP telah ditambah dalam komposit G / Sn dan kesan terhadap jenis PP, nisbah Sn dan suhu pengacuan mampatan dalam G / Sn / PP (LD-PP dan HD-PP) komposit pada sifat-sifat elektrik dan mekanikal telah dikenalpasti. Berdasarkan keputusan yang diperolehi, komposit G / Sn / HD-PP telah menunjukkan sifat-sifat elektrik dan mekanikal yang lebih baik berbanding dengan komposit G / Sn / LD-PP. Sementara itu, bagi suhu membentuk untuk LD-PP adalah 170°C manakala bagi HD-PP adalah 175°C. Akhir sekali, nisbah berat optimum bagi G / Sn / PP (LD-PP dan HD-PP) komposit adalah 15 wt.% nisbah berat Sn disebabkan kekonduksian elektrik yang tinggi, ketumpatan pukal dan nilai kekuatan yang baik.

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AFC	-	Alkaline Fuel Cell
Al	-	Aluminum
ASTM	-	American Society for Testing and Material
BC	-	Before Century
CB	-	Carbon Black
CF	-	Carbon Fibre
CNT	-	Carbon Nanotubes
CPCs	-	Conductive Polymer Composites
CNC	-	Computer Numerically Controlled
Cu	-	Copper
DMFC	-	Direct Methanol Fuel Cell
DOE	-	Department of Energy
EDX	-	Energy Dispersive X-ray
FCV	-	Fuel Cell Vehicle
GDL	-	Gas Diffusion Layer
G	-	Graphite
H_2	-	Hydrogen
H_2O	-	Water
H_3O^4	-	Hydronium ion
HD-PP	-	High density- Polypropylene
ICPs	-	Intrinsically Conductive Polymers
KOH	-	Potassium Hydroxide
LD-PP	-	Low density- Polypropylene
MCFC	-	Molten Carbonate Fuel Cell
MEA	-	Membrane Electrolyte Assembly
Ni	-	Nickel

O_2	-	Oxygen
OCP	-	Open Circuit Potential
PAFC	-	Phosphoric Acid Fuel Cell
Pb	-	Lead
PE	-	Polyethylene
PEM	-	Polymer Electrolyte Membrane
PEMFC	-	Polymer Electrolyte Membrane Fuel Cell
PM	-	Powder Metallurgy
PP	-	Polypropylene
PPS	-	Polyphenyl sulphide
PSU	-	Polysulfone
Pt	-	Platinum
PTFE	-	Polytetrafluoroethylene
PVDF	-	Polyvinylidene fluoride
SEM	-	Scanning Electron Microscope
Sn	-	Stannum
SnO_2	-	Tin oxide
SOFC	-	Solid Oxide Fuel Cell
SS	-	Stainless Steel
Ti	-	Titanium
wt.%	-	Weight ratio

LIST OF SYMBOLS

π	-	Pi
S	-	Distance of 3-point probe
v	-	Test data

LIST OF PUBLICATIONS

Masron, F., Selamat, M.Z., Tahir, M.M., Daud, M.A.M., Sahari, J., 2016. Effect of Molding Temperature on Properties of Graphite/Stannum/Polypropylene Composites**.** *Proceedings of Mechanical Engineering Research Day 2016*, pp.59-160.

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