

Effect of molding temperature on properties of graphite/stannum/polypropylene composites

F. Masron^{1,2,*}, M.Z. Selamat^{1,2}, M.M. Tahir^{1,2}, M.A.M. Daud^{1,2}, J. Sahari³

¹⁾ Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

²⁾ Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

³⁾ Institut Sel Fuel, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

*Corresponding e-mail: farahmasron@yahoo.com

Keywords: PEMFC; composite bipolar plate; graphite

ABSTRACT – The great efforts have been made over the past decades in developing the advance PEMFC technology especially for bipolar plate sector. Unfortunately, factors such as durability and cost of bipolar still remain as the major barrier to commercialization of high efficiency Polymer Electrolyte Membrane Fuel Cell. In this study, Graphite/Stannum/Polypropylene composite has been fabricated by compression molding process with several different temperatures (170 to 180⁰ C), several weight percentage of Stannum (10 to 20 wt%) and have be tested with several mechanical and electrical tests. The result shows that the temperature of 175⁰ C with 15 wt% of Stannum give the best properties.

1. INTRODUCTION

One of the most important part in Polymer Electrolyte Membrane Fuel Cell (PEMFC) is bipolar plate. Almost 80% of stack weight and 60% of stack cost depends on bipolar plate. PEMFC is potentially become most promising power source due to its advantages such as high efficiency, large power density, low operating temperature, and quick start-up [1]. Department of Energy (DOE) had specified the requirements that related to electrical, mechanical, thermal and chemical properties of bipolar plate as shown in Table 1.

Table 1 DOE target for bipolar plates [2].

Property	Value
In-plane electrical conductivity	>100 S/cm
Flexural strength	≥25 MPa
Bulk Density	<1.9 [g/cm ³]
Shore hardness	>50

Previously, Graphite (Gr) bipolar plate has been widely used due to excellent chemical, thermal and electrical properties [3]. However, manufacturing cost for Gr bipolar plate become increased due to machining process of the flow channel. Other than that, Gr inherent brittleness, high permeable to gasses and exhibit poor mechanical properties. Due to Gr brittleness, for the channel fabrication process must to be done by machining process which time consuming and costly process [4]. Compared to metallic material bipolar plate,

they offer higher mechanical strength, low permeability, high conductivity manufacturability but exposed to corrosion which highly potential to be at anode and cathode of operating PEMFC.

As material used for steel can's coating, Stannum (Sn) also commonly known as Tin, have been applied as solder materials, bearing materials, alloying elements, super conducting magnet, electromagnetic materials, sodium ion battery and also pewter [5]. However, there is no report about Gr/Sn composite applied as bipolar plate materials yet.

Recently, Polypropylene (PP) has been widely chosen as most favorable resin to be applied as bipolar plate material due to low cost, easy processability and also high mechanical properties. Combining various conductive fillers is one of the effective ways to develop high electrical conductivities and also good mechanical properties. However, the effect of Sn in Gr/Sn/PP composite as bipolar plate still not much reported. The objective of this study is to investigate the effect of molding temperature of Gr/Sn/PP composite as bipolar plate.

2. METHODOLOGY

Three loadings ratio of Gr/Sn composites were prepared by 70/10, 65/15 and 60/20 respectively while loading ratio of PP remain constant, 20% of the composite. These composition will be dry mixed using ball mill machine for four hours. After that, the composite will be placed in mold and hot compression molding begun. Specimens compressed at 65 ton for 8 minutes at three different temperature, 170°C, 175°C and 180°C. The effect of compression molding temperature on the properties of Gr/Sn/PP composites such as electrical conductivity, bulk density and shore hardness were investigated.

3. RESULTS AND DISCUSSION

3.1 Effect of molding temperature on electrical conductivity

The electrical conductivity of Gr/Sn/PP composites with 10, 15 and 20 wt% of Sn loadings are shown in Figure 1. For 170 and 180°C of molding temperatures, electrical conductivity decreased as the Sn loading is

increased. While for 175°C, by adding the 15 wt% of Sn, electrical conductivity has increased (240 S/cm) but finally decreased at 20 wt% of Sn (100 S/cm). According to the result, the highest electrical conductivity shows by the 10 wt% of Sn loading with molding temperature was 170°C (265 S/cm). In the other side, the lowest value of electrical conductivity showed by 180°C of molding temperature at 20 wt% of Sn loading (6.61 S/cm).

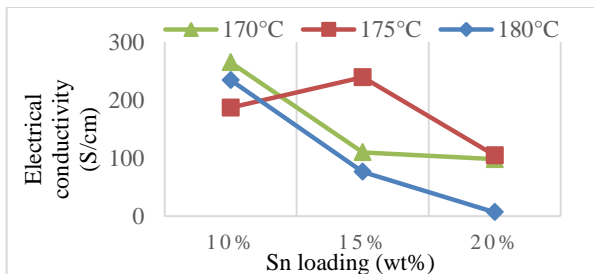


Figure 1 Electrical conductivity (S/cm) versus Sn loadings (wt%).

3.2 Effect of molding temperature on bulk density

Figure 2 showed the bulk density for Gr/Sn/PP composites and the bulk density has decreased with the addition of Sn loadings for 175°C and 180°C of molding temperatures. For 170°C of molding temperature, the bulk density increased with the addition of Sn. The minimum value was 1.46 showed by 10 wt% of Sn loading at 170°C. Besides that, the density value of all samples are meet the DOE requirement which is less than 1.9 g/cm³. The slightly difference of density value is due to additional of Sn loadings in the composite.

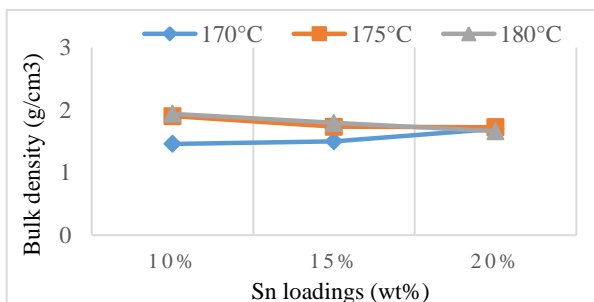


Figure 2 Bulk density (g/cm) versus Sn loadings (wt%).

3.3 Effect of molding temperature on shore hardness

Figure 3 shows the shore hardness results for Gr/Sn/PP composites and for molding temperatures of 175°C and 180°C the values of hardness property is quit close as compared to temperature of 170°C. The highest value obtained by 15 wt% of Sn at 180°C of molding temperature (63). For the lowest value of hardness obtained by all samples at 170°C of molding temperature (26.8 to 28.2). For 175°C of molding temperature, the hardness decreased by addition of Sn loading to 15 wt% and slightly increased by addition of Sn loading to 20 wt%. As compared to 180°C, the hardness has increased by addition of Sn loading to 15

wt% but then decreased slightly when Sn loading up to 20 wt%. In this study, all specimens for 175°C and 180°C of molding temperatures were achieved the DOE requirement but for 170°C of molding temperature, all specimens were below DOE value.

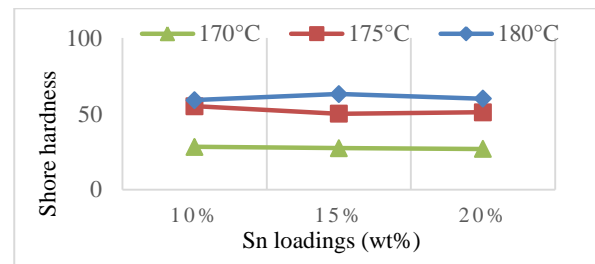


Figure 3 Shore hardness versus Sn loadings (wt%).

4. CONCLUSION

The addition of Sn obviously has a significant effect on electrical, bulk density and shore hardness values. The molding temperature of 175°C was shown as the most suitable temperature in order to produce high electrical conductivity. Other than that, 175°C of molding temperature also showed the results of bulk density and shore hardness that achieved the DOE requirements. A further study about mechanical properties such as flexural strength should be pursued.

ACKNOWLEDGEMENT

The authors would like to thank the Malaysia Ministry of Higher Education, Malaysia and Ministry of Science, Technology and Innovation for sponsoring this work under Grant FRGS/2/2014/SG06/FKM/02/F00237 and Universiti Teknikal Malaysia Melaka (UTeM).

REFERENCES

- [1] Y. Hung, H. Tawfik, and D. Mahajan, "Effect of terminal design and bipolar plate material on PEM fuel cell performance," *Smart Grid Renew. Energy*, vol. 04, no. 01, pp. 43–47, 2013.
- [2] M. C. L. de Oliveira, G. Ett, and R. A. Antunes, "Materials selection for bipolar plates for polymer electrolyte membrane fuel cells using the Ashby approach," *J. Power Sources*, vol. 206, pp. 3–13, May 2012.
- [3] M.Z. Selamat, J. Sahari, N. Muhamad, and A. Muchtar, "The effects of thickness reduction and particle sizes on the properties graphite – polypropylene composite," *Composites*, vol. 6, no. 2, pp. 194–200, 2011.
- [4] S. Karimi, N. Fraser, B. Roberts, and F.R. Foulkes, "A review of metallic bipolar plates for proton exchange membrane fuel cells: Materials and fabrication methods," *Adv. Mater. Sci. Eng.*, vol. 2012, pp. 1–22, 2012.
- [5] M.K. Datta, R. Epur, P. Saha, K. Kadakia, S.K. Park, and P.N. Kumta, "Tin and graphite based nanocomposites: Potential anode for sodium ion batteries," *J. Power Sources*, vol. 225, pp. 316–322, 2013.