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Graphite Coating of Aluminum Bipolar Plate Using Compression Molding Method

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Abstract. Bipolar plate is one of the most important and quite expensive parts of Proton Exchange Membrane Fuel Cell (PEMFC). This research was conducted to compare the value of electrical conductivity, microstructure and flexural strength of the bipolar plate that acts as conductor based on the composition of the bipolar plate. The mass composition of the graphite and epoxy resin are at 60:40, 70:30 and 80:20 was used in compression molding process at 6 tons in 30 minutes. Electrical conductivity tests, microstructural observations and bending tests were carried out. It was found that the high electrical conductivity value at 50 S.cm⁻¹ and best microstructure surface in 80:20 specimen. As for the bending test, the highest value at 101.9MPa is found on 60:40 specimen. The results show that higher composition of graphite will elevate the electrical conductivity and higher composition of epoxy resin will elevate the bending test value of the aluminum bipolar plate.

INTRODUCTION

In a PEMFC system, bipolar plate has a critical role as the medium for water and hydrogen. These two are the source of the energy in fuel cell. PEMFC operates at low temperature and due to this, it requires pure hydrogen as the energy source [1]. With its low operating temperature and zero emissions, PEMFC became one of the most effective and popular source of energy [2-4]. Due to the low operating temperature, PEMFC also commonly refer to as low-temperature PEMFC (LT-PEMFC). Hence why the bipolar plate must have a good ability for conducting the electric.

Metals, due to its good electrical conductivity suited as the material for the bipolar plate. Metallic plate will produce better conductivity but at the same time it poses problems such as corrosion. Metallic material such as aluminum produce impressive electrical and thermal conductivity with also good mechanical properties [5]. From the economical point of view, it is not desirable to use metals for mass production. Even though the use of noble metal is a possibility, but again it is not feasible due to the cost. As an alternative, metallic polymer plate is developed to handle the corrosion problem while at the same time maintaining a good electrical conductivity.

Graphite is a well known material in the bipolar plate advancement. It exhibits good electrical and thermal conductivity [6], suitable to handle the corrosion problem at the cost of still lower conductivity compared to metals. Developing composite plate by adding graphite with metals were done in recent research and obtained better electrical conductivity and peak power output [7]. Several research utilizing Ti as a coating and found better corrosion resistance and electrical conductivity [8-9]. Graphite coating is utilized by methods such as injection molding, compression molding and etc depends on the materials used.

Compression molding is more fitting as manufacturing method of bipolar plate compared to machining process because the production cost is more expensive for machining. Machining process is gradually eliminated due to this reason [10], even though it is possible to applied machining process for the fabrication of the flow channel of a bipolar plate. For graphite coating aluminum process it is easier for the fabrication using compression method. This method is also popularly used for researching the effect of the varied composition of materials used for bipolar plate. The composition of the graphite into the aluminum will be researched. The composition ration will be between the graphite and epoxy resin that acts as the binder or adhesive.

METHOD

Materials and Equipments

These were the equipments used for supporting this research :

- a) Aluminum plate AA1100
- b) Specimen molding with the dimension of 12cmx12cmx1cm
- c) Amorphous Graphite produced by Evergreen Industries as the coating of the plate
- d) Epoxy resin as an adhesive

- e) Aquades water to remove dirt from the specimen
- f) Conductivity tester
- g) Olympus BX53M Microscope
- h) Bending machine

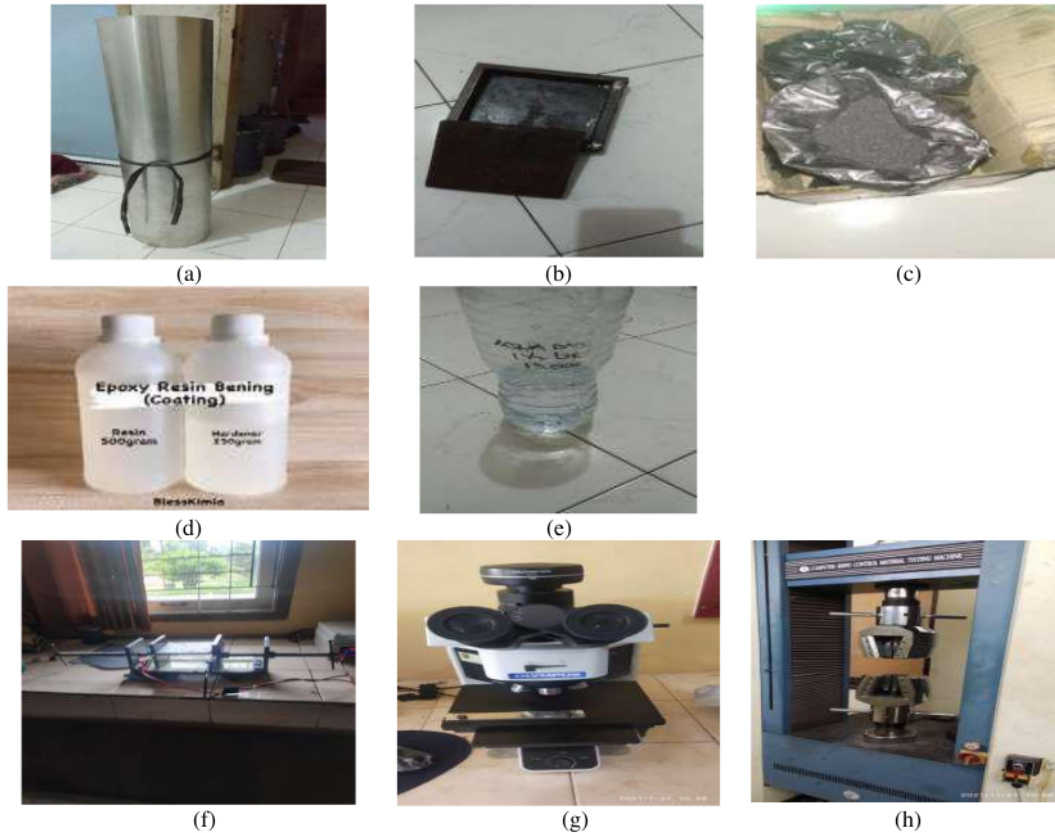


Figure 1. Materials and equipments in the research

Procedure

This research used aluminum plate that coated by graphite and epoxy resin as the specimen. Aluminum plate was put in the molding then coated and subjected to compression for coating process in a mold with dimension of 12cmx12cmx1cm. The compression molding were done with 6 ton force during 30 minutes. There were 3 types of composition between graphite and epoxy resin, namely were 60:40, 70:30 and 80:20 ratio based on the mass. The mass was calculated based on the volume of the mold and density of both graphite and epoxy resin.

When the specimens were collected from the mold, the specimens cleaned by aquades to remove any possible dirt. Some tests were carried out to determine the effect of the variation on the composition. The tests were electrical conductivity measured by conductivity tester using ASTM B193 standard, microstructure observation using Olympus microscope and bending test by bending machine. The tests are done in Laboratory of Department of Mechanical Engineering Universitas Islam Riau. All materials and equipment for the research are shown by figure 1a to 1h.

RESULTS AND DISCUSSIONS

Here are the results of the test on the specimens. There were 3 tests done, they were electrical conductivity, microstructure and bending test.

Electrical Conductivity Test

Table 1. Electrical conductivity of specimens

No	Composition (%)	Conductance (S)	Electrical Conductivity (S.cm-1)
1	60 : 40	142	14.2
2	70 : 30	250	25
3	80 : 20	500	50

Table 1 shows the average value of electrical conductivity of the 3 types of bipolar plate measured by the conductivity tester. The lowest value of electrical conductivity is at composition of 60:40 with 14.2Scm^{-1} and the highest is at composition 80:20 with value of 50Scm^{-1} . It is clear that the higher composition of graphite will increase the electrical conductivity of a plate. This could be resulted due to the nature of graphite that had good conductivity. Figure 3 below shows the trend of the electrical conductivity on different composition. There is a quite significant increase in conductivity between composition 70:30 to 80:20 compared with 60:40 to 70:30.

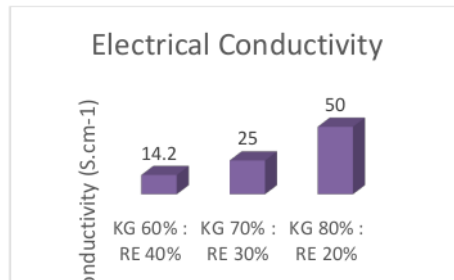


Figure 2. Electrical conductivity

Microstructure Observation

Microstructure observation on the 3 types of specimens are done. From figure 3, it is shown that there is uneven distribution of graphite of the specimen 60:40. This is due to the dominant use epoxy resin up to 40 percent and cause the spread of the graphite became not well distributed. This microstructure of specimen with 60:40 composition shows that the surface looks rough dan porous. All of these are cause by the amount of epoxy resin use in the specimen is dominant even though it only used at 40 percent of total.

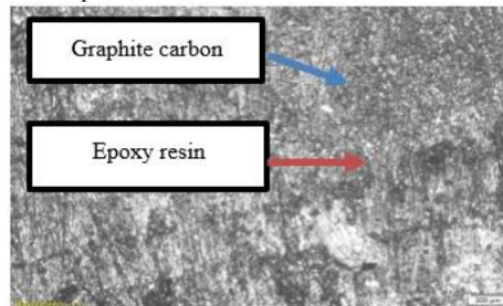


Figure 3. Microstructure of 60% graphite and 40% epoxy resin

The microstructure of 70:30 specimen is shown by figure 4. From the observation, it could be known that the particles of the graphite and epoxy resin are well and evenly distributed. This occur due to the larger amount of graphite used making the surface appears to be smoother. The result of 70:30 microstructure is different compared to the 60:40 with former being less porous than the latter.

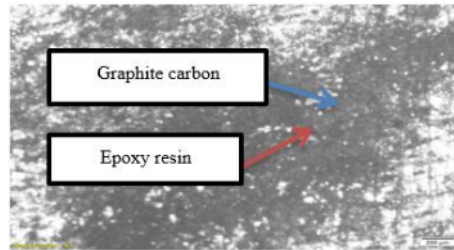


Figure 4. Microstructure of 70% graphite and 30% epoxy resin

The observation of the microstructure of specimen 80:20 is shown by figure 5. Higher composition of the graphite at 80% and lower epoxy resin at 20% cause better surface and particle's distribution. This specimen has the best distribution of particles and smoothest surface among all the specimens. While the epoxy resin did bind the aluminum and graphite, it is the increasing concentration of graphite that affect the distribution of particles and also the surface quality.

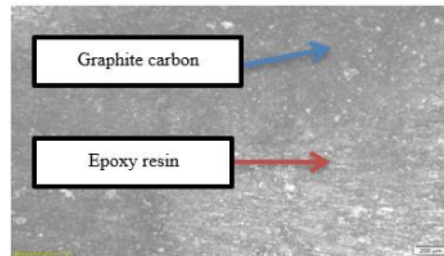


Figure 5. Microstructure of 80% graphite and 20% epoxy resin

Bending Test

The results of the bending test are done and table 2 below shows the value from each specimen.

Table 2. Bending test result

Composition (%)	Area (Mm ²)	Max. Force (MPa)
60 : 40	464.400	101.9
70 : 30	635.100	65.3
80 : 20	623.200	21.9

Based on the table 2 above, the lowest value of the bending test is on the specimen with composition of 80:20 with 21.9 MPa and the highest is on specimen with composition of 60:40 with 101.9MPa. Specimen 70:30 has value in between the two of 60:40 and 80:20 with 65.3MPa. Figure 6 shows the trend of the increasing value of the bending test from specimens. It is seen that the increase use of the epoxy resin will also increase the bending test value of the specimen. Significant difference of bending test value between each specimen is noted in this graph. This occurred because the epoxy resin acts as the adhesive between aluminum and graphite. Hence, the increase of the epoxy resin will increase the bending value of an aluminum plate.

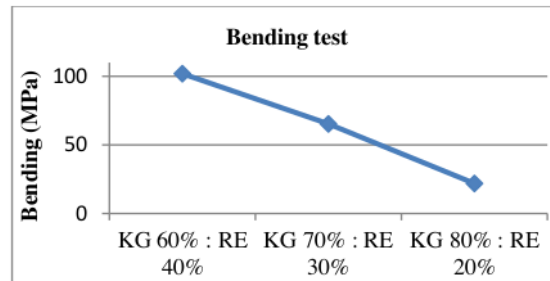


Figure 6. Bending test

CONCLUSION

In conclusion, the composition of the graphite and epoxy resin affects the electrical conductivity, microstructure and bending test of the aluminum plate. From the research, higher composition of graphite will increase the electrical conductivity, better particles distribution and surface quality. As for the epoxy resin, higher composition of it will increase the bending test value of the aluminum plate. For the future research, it is critical to find the right composition of graphite to obtain good electrical conductivity while at the same time getting good bending test value for the aluminum plate that used for fuel cell bipolar plate.

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