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Epoxy/carbon black/graphite composite bipolar plate prepared by high speed mixing technique

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ABSTRACT – Conducting polymer composite (CPC) has produced used epoxy resin (EP), carbon black (CB) and graphite (G) as main composition. Various weight percentage (wt.%) of CB, G and EP has been selected. The fillers (CB and G) were mixed together with the matrix (EP) used high speed mixer with no heat treatment. The mixture was poured into the steel mold and formed used hot pressed. After that, all sample's electrical conductivity and flexural strength had been measured and the properties of EP/CB/G composite was analyzed. The result found that the best plate produced was the 20/25/55 of EP/CB/G weight ratio (wt.%). It has 102 S/cm in-plane electrical conductivity and 12 MPa flexural strength.

1. INTRODUCTION

The biggest obstacle in the commercialization of fuel cell vehicle (FCV) is the economic cost and durability. The current situation of fuel cell system cost for vehicle application, according to US Department of Energy (DOE), is still more than twice as expensive as other conventional and advanced vehicle technologies [1]. The important component of fuel cell system is the fuel cell stack. The stack is mainly constituting of bipolar plate which contribute 80% of the stack weight and almost 50% of stack cost [2]. Hence, the investigation on cost/performance materials of bipolar plate has become a critical research. The graphite-based composites offer good electrical conductivity and economical processing [3]. Addition of filler such as carbon black or carbon nanotube to the graphite matrix has resulted in a bipolar plate that has electrical conductivity above expected value, but still its mechanical strength is still below expectation [4-7]. The aim of this study is to apply the high speed mixing technique in the fabrication of graphite-based bipolar plate to meet DOE expectation as shown in Table 1 below.

Table 1 DOE technical targets for bipolar plate [1].

Property	2015 Status	2025 Targets
Electrical conductivity	> 100 [Scm^{-1}]	> 100 [Scm^{-1}]
Flexural strength	> 34 [MPa]	> 25 [MPa]

2. MATERIALS AND METHODS

2.1 Materials

The conductive filler materials used in this study were carbon black (CB) and graphite (G), while the binder was epoxy (EP). The G powder was supplied by Asbury Carbon Inc., that has density of 1.7 g/cm^3, surface area of 1.5 m^2/g, particle size of 59 µm and 99% of purity. The CB was also provided by Asbury Carbon Inc., that has density of 0.096 g/cm^3, has surface area of 254 m^2/g, average particle size of 30 nm, and 99% of purity. The epoxy resin was 105 West System Epoxy Resin/206 Slow Hardener wich has viscosity of 725 cps.

2.2 High speed mixing

Before the high speed mixing technique is applied, samples were prepared by following steps. Firstly, powder mixtures of CB and G were made by different wt.% using a ball milling. To get a homogenous mixture, the powder was mixed at rotating speed of 200 rpm for one hour. Lastly, the powder mixture and epoxy were mixed in the high speed mixer (Waring) at 1900 rpm speed for 10 minutes. The liquid epoxy resin and curing agent used in the mixture was 6:1 ratio, which is an acceptable ratio recommended by the manufacturer. The various composition of EP/CB/G shown in Table 2. The composition mixture then poured into steel mould at molding temperature 80 ^{0}C and 30-ton pressure for 30 minutes.

Table 2 The composition of composite EP/CB/G based on weight %.

Filler		Binder
G %	**CB%**	**EP%**
60	20	20
55	25	20
50	30	20
45	35	20

2.3. In-plane electrical conductivity

The in-plane electrical conductivity of the EP/CB/G composite was measured by a Jandel Multi Height Four Probe as per ASTM C611.

2.4. Flexural strength

The static Universal Testing Machine (Instron) was used to measure the sample flexural strength according to ASTM D70 at room temperature. The dimension of samples was 100 mm x13 mm x 5 mm, the support span length of each sample was fixed at 70 mm and the cross head speed was 2 mm/min.

3. RESULTS AND DISCUSSION

All of the various composition of EP/CB/G was successfully fabricated except that the 20/35/45 composition has failed. It was due to the bonding of graphite and carbon black with EP is weak. Graphite has poor wettability with the binder resin, while carbon black has very large specific surface area [8-10]. Therefore, lack of bonding to the conductive fillers during the fabrication process of 20/35/45 composition produce the defect of composite structure.

3.1 In-plane electrical conductivity

Figure 1 shows the effect of addition carbon black (CB) as the second fillers in the G/epoxy composite. The in-plane electrical conductivity of the EP/CB/G composites has double from 20 wt.% to 25 wt.% of CB content. The highest value of in-plane electrical conductivity belongs to 20/25/55 composition of EP/CB/G and the 102 S/cm of value has met the DOE target. This phenomenon may be attributed to the better dispersion of carbon black into the G/epoxy composite during high speed mixing. Carbon black help build better conductive pathway throughout the plate. Nevertheless, addition of more than 25 wt.% of CB decreased the in-plane conductivity because the epoxy resin as a matrix is not sufficient enough to bind the fillers. Similar trend of in-plane electrical conductivity also found in other study, such as Dweiri and Sahari [4], Suherman et.al [6], and Mathur et.al [8].

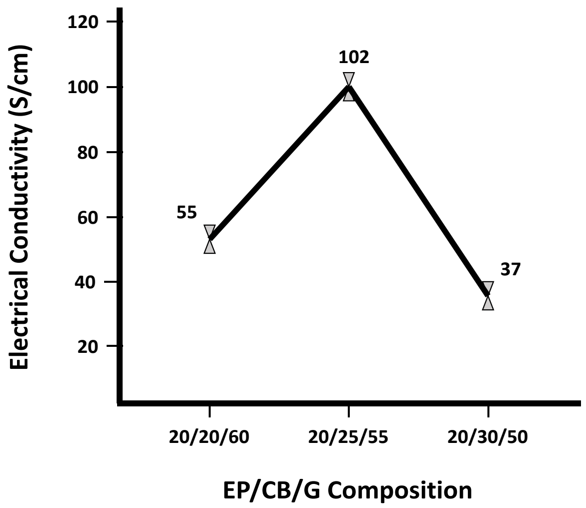

Figure 1 Electrical conductivity (Average).

3.2 Flexural strength

Figure 2 shows the trends of flexural strength from the addition of CB to the G/epoxy composite. Similar to the in-plan electrical conductivity above, the highest value of flexural strength belongs to the 20/25/55 composition of EP/CB/G with the value of 12 MPa. However, the value does not meet the DOE target. These phenomena also present in other study that use epoxy as binder such as Suherman et.al [6].

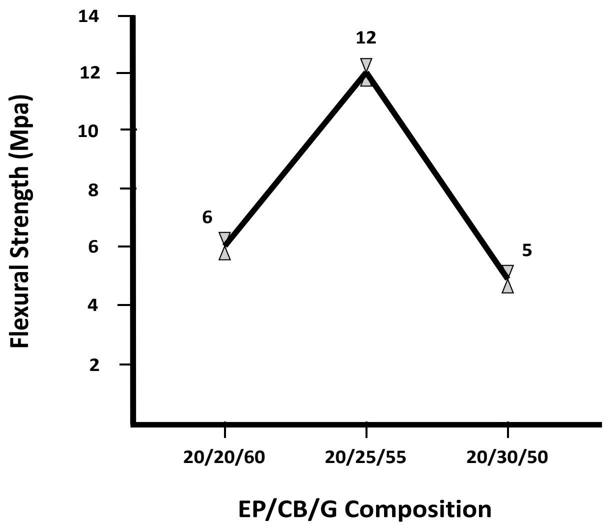

Figure 2 Flexural strengthy (Average).

4. CONCLUSION

The application of the high speed mixing technique in fabrication of graphite-based bipolar plate has resulted in a similar in-plane electrical conductivity's and flexural strength's trend with other previous study but simpler in the procedure.

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