Effect of Particle Size and Graphite Loading Concentration on the Electrical Conductivity of Graphite/Epoxy Composites

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Abstract: *Graphite/epoxy composite isa potential candidate for conductive polymer composites (CPCs). The problem of CPC is low electrical conductivity, so need the high conductive fillers with different particle size to improve it. Two types of conductive fillers synthetic graphite (SG) and natural graphite (NG) powders with average particle sizes of 74μm and 30μm were used in this study. Graphite with different weight percentage, types and sizes were added into the epoxy resin as matrix. Dispersion of graphite in epoxy resin was conducted by high speed mixer through mechanical shearing mechanism. The mixture of graphite/epoxy suspension was poured into the mold, casting process was conducted for manufacturing of graphite/epoxy composites. The electrical conductivity composite by variation of graphite loading concentration was measured by Jandel four point probes. Agglomeration of graphite in epoxy resin as matrix was observed on fractured surface by scanning electron microscopic. The electrical conductivity of graphite/epoxy composites were increased by the increasing of graphite loading concentration,and reached the highest value at 75wt.%.*

Keywords:*Conductive polymer composites, electrical conductivity, casting process*

1. Introduction

Some factors that mainly related with the electrical conductivity of composite materials are the conductive filler concentration, the shape and size of thoseparticles,the adhesion between the host phase and the matrix, the processing method, andpossible interactions between the non-conductive and the conductive phase [1]. Polymer matrix as conductive polymer composite has some advantages, such aslightweight, lower cost, good mechanical properties, good corrosion resistance, and good gas tightness. The disadvantage is that polymers has extremely low electrical conductivity, that make it is difficult to get sufficient mechanical properties and high conductivity simultaneously. The high electrical conductive plate needs the high conductive filler loadings that exceed percolation threshold concentrations, and approach the critical pigment volume concentrations (CPVC) of 50-70 % in volume [2]. Above the CPVC, the material would have insufficient carrier polymer and behaves like a solid; so the material does not flow well and the mold can'tfill well during processing.Therefore, some researcher using combination of conductive filler with small and big particle size at high loading concentration of conductive fillers to improve the electrical conductivity of the graphite-based polymer composite [3-4].

An interconnecting path of conductive graphite particles forms at the percolation threshold concentration, and it extends throughout the entire sample, enabling electrons to "percolate". As the material goes through an insulator–conductor transition, the electrical resistance decreases by many magnitude orders. Higher filler loading concentration of graphite makes no enough polymers to carry the graphite particles. Some percolation pathways form to enhanced conductivity, but the materials become porous and weak [2] that makes composite plate materials with high graphite concentration are extremely brittle and poor gas barrier properties. The commonly reinforced filler used are graphite, carbon black, and carbon fiber, incorporated into the composites to improve the properties of composites materialsusing conventional polymer processing (5,6).The effect of particle size and graphite loading concentration on the electrical conductivity of graphite epoxy composites were investigated on this research.

2. Experimental

This study used graphite (SG) and Natural Graphite powder (NG) with particle size 74μm and 30μm, respectively, were supplied by Asbury Carbons, New Jersey, USA. The epoxy resin used was supplied by US

Composites, a bisphenol-A based epoxy resin (635 types), viscosity 6 Poise, while curing agent, 4-Aminophenylsulphone with molecular weight 248 g/mol was received from New Jersey, USA. Diamine type of curing agent is to assist rapid and dense cross-linking of epoxy resins. The epoxy and curing agent with ratio 3:1 in wt. % were poured into the biker, mixed using the mechanical mixer (RW 20-KIKA-WERK) at 1200 rpm for 40 s. SG and NG with different loading concentration were added into the epoxy and curing agent mixture, and mixed again using mechanical mixer at 1200 rpm for 3 min, so the epoxy resin can be intercalates inside the conductive fillers, especially into the graphite pores and inter layers. The composites obtained put in a steel mould, and then pressed into 25 mm diameter discs at temperature 100 °C and curing pressure 750 Psi for 1.5 hours for electrical conductivity and fracture surface measurements. The conductivities of the disc in the plane direction were determined by Jandel four point prove combined with a RM3 test unit, which had a constant current sources and digital voltmeter designed especially for the four point measurements. Fracture surface morphologywas examined using scanning electron microscopy (SEM, Model Supra 55/55VP).

3. Results and Discussion

3.1. The electrical conductivity of SG/epoxy and NG/epoxy composites

The electrical conductivity of epoxy composite in weight percentage of SG (synthetic graphite) and NG (natural graphite) are shown in Figure.1.This figure show that SG and NG addition increase the electrical conductivity at any level, although NG (30μm) give the higher value of electrical conductivity in contrast.

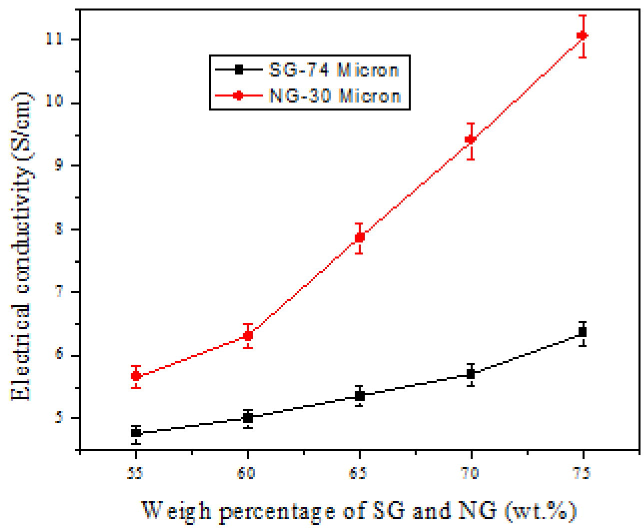

Fig.1: Electrical conductivity of SG/epoxy and NG/epoxy composites

NG addition increase the electrical conductivity from 5.645 S/cm (55 Wt.%), 6.3 S/cm (60 Wt.%), 7.85 S/cm (65 Wt.%), 9.4 S/cm (70 Wt.%), and 11.5 S/cm (75 Wt.%) as the highest. SG as a filler addition was also increased the electrical conductivity although it value wasn't as high as NG, start from 4.75 S/cm (55 Wt.%), 5 S/cm (60 Wt.%), 5.35 S/cm (65 WT.%), 5.7 S/cm (70 Wt.%), and 6.35 S/cm (75 Wt.%). From the data above can be concluding that small particle size of graphite is helpful in reducing the viscosity (increase flow ability) of the compound-melt. The lower binder absorption of small particles helps dispersing more graphite particles within the binder. According to this, it is to annotate here that for comparison of compounds with same filling content (gravimetric) the total surface area of many small sized particles is higher than of larger particles [6-7]

3.2. Fracture surface of Graphite/epoxy Composites

Fig.2 show Scanning electron microscopic (SEM) image of the graphite/epoxy composites specimenwith different scale bar. The fracture surface structure with different magnification size was also observed under SEM on this figure. Graphite addition increased the viscosity of the epoxy, caused less energy transfer during mechanical mixing which will affect the dispersion of the graphite into the polymer matrix.

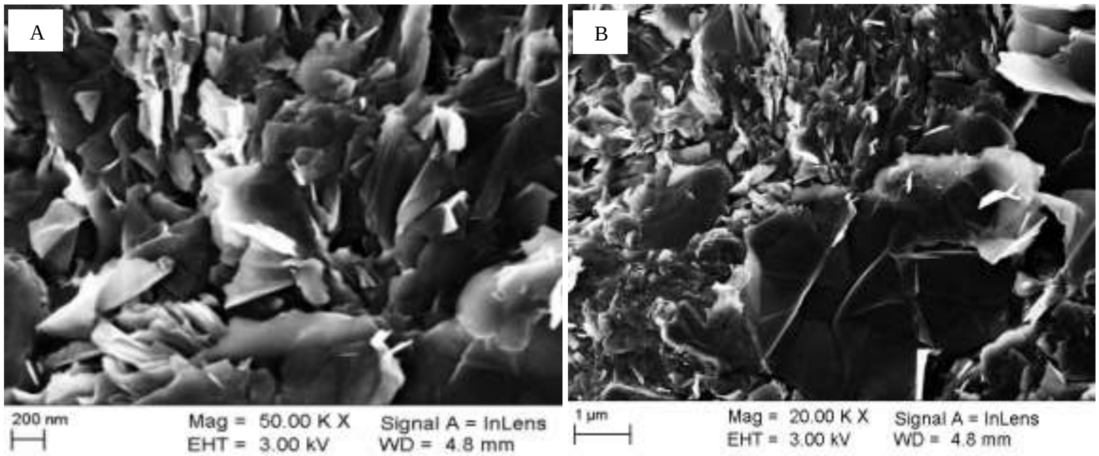

Fig.2: Fracture surface of graphite/epoxy composites with contents (in wt.%) of 80/20 with scale bar (a) 200 nm and (b), 1 µm respectively.

4. Conclusions

This research investigated the effect of particle size and graphite loading concentration on the electrical conductivity of graphite/ epoxy composites. This study showed that graphite epoxy composites performances is related to graphite particle size. For flake-like graphite, electrical conductivity of natural graphite with average particle size 30µm higher than synthetic graphite with average particle size 74 µm at the same weight percentage (Wt.%) of conducting filler loading concentration. The highest values are 11.05 S/cm and 6.35 S/cm at (75 Wt. %) respectively.

5. Acknowledgements

The authors gratefully acknowledge the financial support given for this work by the Directorate General of Higher Education, 2015 with contract number: SP DIPA-023.04.1.673453/2015, 14 November 2014, for Kopertis Wilayah X, number: 14/Kontrak/ 010/ KM/ 2015, Indonesia.

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