# MECHANICAL AND THERMAL PROPERTIES OF GRAPHENE OXIDE REINFORCED ACRYLATED EPOXIDISED PALM OIL/UNSATURATED POLYESTER RESIN

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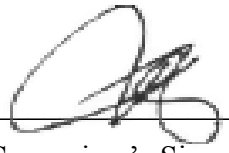
We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.



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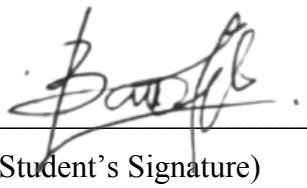
I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.



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## ABSTRAK

Kelapa sawit berpotensi menjadi resin polimer, bagi mengurangkan kebergantungan pada polimer sintetik. Namun begitu, minyak sawit adalah minyak yang tidak kering yang sukar dikeraskan. Kajian ini dilakukan untuk mengurangkan kebergantungan terhadap sumber petroleum oleh polimer sintetik dengan mencampurkan minyak kelapa sawit dalam polimer sintetik, poliester tak tepu (UPE) dan diperkuat dengan grafena oksida (GO) dan diawet dengan ketuhar. Dalam tesis ini, kepekatan minyak sawit terepoksi akrilat (AEPO) adalah 10, 20 dan 30 wt% dan grafena oksida (GO) masing-masing 0.03, 0.05, 0.07 dan 0.1 phr. Kesan nisbah muatan AEPO dan GO yang berbeza dalam campuran resin UPE/AEPO/GO dikaji secara khusus sifat mekanikal, morfologi dan termal. Pra-perincian resin UPE/EPO telah dilakukan menggunakan spektroskopi inframerah transformasi Fourier (FTIR). Minyak sawit terepoksi diaktifkan melalui tindak balas dengan asid akrilik untuk membentuk AEPO. Langkah kedua adalah untuk mensintesis grafena oksida dari grafit menggunakan kaedah Hummer yang diubahsuai. Grafit telah menjalani pra-oksida sebelum menjalani proses pengoksidaan. Grafit oksida yang terhasil disonikasi untuk memisahkan grafit menjadi kepingan GO. Ciri khas AEPO, GO yang disintesis dan interaksi antara UPE/AEPO/GO dikaji melalui spektroskopi inframerah transformasi Fourier (FTIR) dan Resonans Magnet Nukleus (NMR). Sifat mekanik dikaji melalui kekuatan tegangan, modulus Young, pemanjangan pada waktu rehat dan ujian impak Izod. Sifat termal sampel dikaji melalui Analisis Termogravimetri (TGA) dan Analisis Mekanikal Dinamik (DMA). Morfologi resin dikaji melalui Mikroskop Elektron Pengimbas (SEM). Peregangan C=C telah mengesahkan kumpulan fungsi akrilat berbanding spektrum EPO FTIR pada panjang gelombang 1618 hingga 1635 $cm^{-1}$. Kumpulan berfungsi dalam grafena oksida seperti karbonil (C=O) dan hidroksil (-OH) dilihat dalam spektrum GO FTIR dengan panjang gelombang pada 1767 $cm^{-1}$ dan 1324 $cm^{-1}$. AEPO yang berjaya diikat ke UPE disahkan apabila panjang gelombang C=O yang beralih ke panjang gelombang lebih rendah berbanding spektrum FTIR UPE asli. Campuran UPE/AEPO menunjukkan kekuatan tegangan yang lemah berbanding UPE. Penambahan 0.1 phr GO hingga 10 % berat AEPO meningkatkan kekuatan tegangan dan kekuatan hentaman komposit masing-masing sebanyak 18.8 % dan 48.10 %. Gambar SEM 90/10/0.1 (UPE/AEPO/GO) campuran resin menunjukkan permukaan goresan panjang dan selari berserta lompang kecil dan serpihan putih kecil yang menunjukkan penyebaran GO yang sekata. Pada 0.07 phr GO dan 10 % berat AEPO, modulus Young meningkat ke 388 %. Namun begitu, pemanjangan pada waktu rehat komposit UPE/AEPO/GO menurun. Dari hasil TGA, penambahan 0.1 phr GO hingga 10 % berat meningkatkan degradasi utama UPE sebanyak 15.5 °C. Ia mencerminkan kestabilan terma yang lebih tinggi. Dari hasil DMA, modulus penyimpanan, puncak tertinggi modulus kehilangan dan suhu pada puncak UPE/AEPO/GO lebih rendah daripada UPE asli. Pada adunan 90/10/0.1 (UPE/AEPO/GO), modulus kerugian maksimum adalah 21.4 % iaitu lebih tinggi berbanding campuran UPE/AEPO kerana kekonduksian terma GO yang lebih tinggi. Suhu peralihan kaca (Tg) juga berlaku pada suhu yang lebih tinggi daripada 0 phr GO dan puncak tan δ yang lebih luas menjelaskan kepadatan penghubung silang yang tinggi dalam sistem komposit. Hasil dari kajian ini dapat disimpulkan bahawa komposit 90/10/0.1 (UPE/AEPO/GO) adalah campuran yang baik dengan ciri-ciri keseimbangan kekuatan tegangan, hentaman, modulus, pemanjangan dan terma yang membawa kepada aplikasi pada komponen panel rumah, basikal, perabot dan kelengkapan barang rumah.

## ABSTRACT

Palm oil has the potential to be a polymer resin to reduce the dependence on synthetic polymers. However, palm oil is a non -drying oil that is difficult to cure. This study was conducted to reduce the dependence on petroleum resources of synthetic polymers by mixing palm oil in synthetic polymer, unsaturated polyester (UPE) and reinforced with graphene oxide (GO) and cured by oven. In this thesis, the concentrations of epoxy acrylate palm oil (AEPO) were 10, 20 and 30 wt% and graphene oxide (GO) 0.03, 0.05, 0.07 and 0.1 phr, respectively. The effects of different AEPO and GO loading ratios in UPE/AEPO/GO composite mixtures were specifically studied for mechanical, morphological and thermal properties. Characteristic of UPE/EPO resins was performed using Fourier transform infrared spectroscopy (FTIR). Epoxy palm oil was activated by reaction with acrylic acid to form AEPO. The second step was to synthesize graphene oxide from graphite using a modified Hummer's method. Graphite had undergone pre-oxidation before undergoing the oxidation process. The resulting graphite oxide was sonicated to separate graphite into GO flakes. The characteristics of the synthesized AEPO, GO and the interaction between UPE/AEPO/GO composites were studied through Fourier transform infrared spectroscopy (FTIR) and Nuclear Magnetic Resonance (NMR). Mechanical properties were studied through tensile strength, Young's modulus, elongation at break and Izod impact test. The thermal properties of the samples were studied through Thermogravimetric Analysis (TGA) and Dynamic Mechanical Analysis (DMA). The morphology of the resin was studied through Scanning Electron Microscope (SEM). The C = C stretching confirmed the acrylate functional group versus to the EPO FTIR spectrum at wavenumber 1618 to 1635 $cm^{-1}$. The functional groups in graphene oxide such as carbonyl (C = O) and hydroxyl (-OH) were seen in the FTIR spectrum of GO at wavenumber 1767 $cm^{-1}$ and 1324 $cm^{-1}$. A successful AEPO bound to the UPE was confirmed when the C = O wavenumber shifts to a lower wavenumber than the original EPO FTIR spectrum. The UPE/AEPO blends showed weaker tensile strength than UPE. The addition of 0.1 phr GO to 10 % by weight AEPO increased the tensile strength and impact strength of the composite by 18.8 % and 48.10 %, respectively. SEM figure of 90/10/0.1 (UPE/AEPO/GO) composite shows a long and parallel scratch surface along with small voids and small white fragments showing homogeneous GO distribution. At 0.07 phr GO and 10 % by weight AEPO, Young's modulus increased to 388 %. However, the elongation at break of the UPE/AEPO/GO resin mixture decreased. From the TGA results, the addition of 0.1 phr GO to 10 % by weight increased the major degradation of UPE by 15.5 ° C. It reflects higher thermal stability. From the DMA results, the storage modulus, the highest peak of the loss modulus and its temperature are lower than the original UPE. At 90/10/0.1 (UPE/AEPO/GO), the maximum loss modulus was 21.4 % which is higher than UPE/AEPO blends due to the higher GO thermal conductivity. The glass transition temperature (Tg) also occurs at temperatures higher than 0 phr GO and the wider tan δ peak explains the high cross -linking density in this composite. The results of this study can be concluded that the 90/10/0.1 (UPE/AEPO/GO) composite is a good mixture with the characteristics of balance of tensile strength, impact, modulus, elongation and thermal leading to application on home panel components, bicycles , furniture and home furnishings.

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