SURFACE MODIFICATION OF GRAPHENE NANOFILLERS TO IMPROVE THE THERMAL AND MECHANICAL PROPERTIES OF POLYBUTYLENE SUCCINATE-GRAPHENE NANOCOMPOSITES

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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 Doctor of Philosophy in Chemical Engineering.

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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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ANIS SAKINAH BINTI ZAINAL ABIDIN

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<td>$\lambda$</td>
<td>Wavelength of the X-ray</td>
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</table>
LIST OF ABBREVIATIONS

AAc       Poly(acrylic acid)  
ABS       Acrylonitrile butadiene styrene  
AFM       Atomic force microscopy  
Ag        Argentum  
ANOVA     Analysis of Variance  
ATRP      Atom transfer radical polymerisation  
BDO       1,4-butanediol  
C         Carbon  
CCD       Central composite design  
CMG       Chemically modified graphene  
CNT       Carbon nanotube  
CVD       Chemical vapour deposition  
D'inf     Defect derived D peak  
DCC       N,N'-dicyclohexylcarbodiimide  
DDA       Dodecylamine  
DDAB      Didodecyldimethylammonium  
DDMAT     S-1-dodecyl-S’-(α,α’-dimethyl-α’’-acetic acid) trithiocarbonate  
DMDA      N,N'-dimethylacetamide dimethyl acetal  
DMF       Dimethylformamide  
DSC       Differential scanning calorimetry  
DTG       Derivative thermogravimetric analysis  
EDC       1-ethyl-3-(3-dimethylaminopropyl)carbodiimide  
FESEM     Field emission scanning electron microscopy  
FGS       Functionalised graphene sheets  
FTIR      Fourier transform infrared spectroscopy  
FWHM      Full width at half maximum  
G_app     Apparent G  
G_Carbon/O_Carbon     Carbon-carbon and oxidised carbon bond ratio  
GO        Graphene oxide  
GOODA     Graphene oxideoctadecylamine  
HA        Hexylamine  
HATU      2-(7-aza-1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluoro phosphate  
HDA       Hexadecylamine  
HDPE      High density polyethylene  
HGO       Natural graphite oxidation via Hummer’s method  
IFRPBS    Intumescent flame retardant polybutylene succinate  
IGO       Natural graphite oxidation via Tour’s method  
KGO       Expanded graphite oxidation via Hummer’s method  
KIGO      Expanded graphite oxidation via Tour’s method  
LDPE      Low density polyethylene  
LLDPE     Linear low density polyethylene  
MA-g-PP   Maleic anhydride grafted polypropylene  
MMT       Montmorillonite  
N_L       Number of layers  
NMP       N-Methyl-2-pyrrolidone  
OA        Octylamine  

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ODA</td>
<td>Octadecylamine</td>
</tr>
<tr>
<td>PANi</td>
<td>Polyaniline</td>
</tr>
<tr>
<td>PBD</td>
<td>Polybutadiene</td>
</tr>
<tr>
<td>PBS</td>
<td>Polybutylene succinate</td>
</tr>
<tr>
<td>PBSA</td>
<td>Poly(butylene succinate-co-butylene adipate)</td>
</tr>
<tr>
<td>PBST</td>
<td>Polybutylene succinate co butylene terephthalate</td>
</tr>
<tr>
<td>PCL</td>
<td>Poly (e-caprolactone)</td>
</tr>
<tr>
<td>PCU</td>
<td>Poly(carbonate-urea) urethane</td>
</tr>
<tr>
<td>PE</td>
<td>Polyethylene</td>
</tr>
<tr>
<td>PEDOT</td>
<td>Poly(3,4-ethylenedioxythiophene)</td>
</tr>
<tr>
<td>PEN</td>
<td>Poly(ethylene-2,6-naphthalate)</td>
</tr>
<tr>
<td>PEO</td>
<td>Polyethylene oxide</td>
</tr>
<tr>
<td>PET</td>
<td>Poly(ethylene terephthalate)</td>
</tr>
<tr>
<td>PESu</td>
<td>Poly(ethylene succinate)</td>
</tr>
<tr>
<td>PF</td>
<td>Phenol formaldehyde</td>
</tr>
<tr>
<td>PHBV</td>
<td>Poly(3-hydroxybutyrate-co-4-hydroxybutyrate)</td>
</tr>
<tr>
<td>PI</td>
<td>Polyimide</td>
</tr>
<tr>
<td>PLA</td>
<td>Poly (lactic acid)</td>
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<tr>
<td>PLLA</td>
<td>poly(l-lactide)</td>
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<tr>
<td>PMHS</td>
<td>Polymethylhydrosiloxane</td>
</tr>
<tr>
<td>PMMA</td>
<td>Poly(methyl methacrylate)</td>
</tr>
<tr>
<td>PMP</td>
<td>Poly(4-methyl-1-pentene)</td>
</tr>
<tr>
<td>PNC</td>
<td>Polymer nanocomposites</td>
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<tr>
<td>POM</td>
<td>Polarised microscope</td>
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<tr>
<td>POP</td>
<td>Poly(oxypropylene) diamine</td>
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<tr>
<td>POSS</td>
<td>Polyhedral oligomeric silsesquioxanes</td>
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<tr>
<td>PP</td>
<td>Polypropylene</td>
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<tr>
<td>PRESS</td>
<td>Prediction error sum of squares</td>
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<tr>
<td>PS</td>
<td>Polystyrene</td>
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<tr>
<td>PTA</td>
<td>Terephthalic acid</td>
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<tr>
<td>PU</td>
<td>Polyurethane</td>
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<tr>
<td>PVA</td>
<td>Polyvinyl alcohol</td>
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<tr>
<td>PVDF</td>
<td>Polyvinylidene fluoride</td>
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<tr>
<td>RAFT</td>
<td>Reversible Addition-Fragmentation chain Transfer</td>
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<tr>
<td>rGO</td>
<td>Reduced graphene oxide</td>
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<tr>
<td>RSM</td>
<td>Response surface methodology</td>
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<tr>
<td>SLG</td>
<td>Single layer graphene</td>
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<tr>
<td>SWCNT</td>
<td>Single wall carbon nanotube</td>
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<tr>
<td>TEGO</td>
<td>Thermally exfoliated graphene oxide</td>
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<tr>
<td>TEM</td>
<td>Transmission electron microscopy</td>
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<tr>
<td>TGA</td>
<td>Thermogravimetric analysis</td>
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<tr>
<td>THF</td>
<td>Tetrahydrofuran</td>
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<tr>
<td>TPP</td>
<td>Triphenyl phosphate</td>
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<tr>
<td>TTOGODA</td>
<td>Thermal treated graphene oxide/octadecylamine</td>
</tr>
<tr>
<td>TTPBS/GOODA</td>
<td>Thermal treated polybutylene succinate/graphene oxide/octadecylamine</td>
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<tr>
<td>UHMWPE</td>
<td>Ultrahigh molecular weight polyethylene</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Testing Machine</td>
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<tr>
<td>UV-A</td>
<td>Ultraviolet rays 400 Watt</td>
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<tr>
<td>UV-B</td>
<td>Ultraviolet rays 8 Watt</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>XRD</td>
<td>X-ray diffraction</td>
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<tr>
<td>XPS</td>
<td>X-ray photoelectron spectroscopy</td>
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