THE EFFECT OF CHICKEN FEATHER FIBER LOADING AND CHEMICAL MODIFICATION OF RECYCLED HIGH DENSITY POLYETHYLENE/ NATURAL RUBBER/ CHICKEN FEATHER FIBER COMPOSITES

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UNIVERSITI MALAYSIA PERLIS

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by

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LIST OF SYMBOLS, ABBREVIATIONS OR NOMENCLATURE

ABS	Acrylonitrile-butadiene-styrene
AE	Acoustic emission
ASTM	American Society for Testing and Materials
AT	Attapulgite
Br	Bromine
CFF	Chicken feather fiber
CMC	Ceramic matrix composites
CNT	Carbon nanotube
COPE	Copolyester
Cu	Copper
DSC	Differential scanning calorimetry
EB	Electron-beam
EPDM	Ethylene propylene diene monomer
EPM	Ethylene propylene rubber
EVA	Ethylene vinyl acetate
Ff	Feather fiber
FTIR	Fourier transform infrared spectroscopy

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HDPE	High density polyethylene
HIPS	High-impact polystyrene
iPP	Isotactic polypropylene
Kf	Retted kenaf bast fiber
LDPE	Low density polyethylene
LLDPE	Linear low density polyethylene
LNR	Liquid natural rubber
MA-g-PP	Maleic anhydride-grafted-polypropylene
MANR	Maleic anhydride grafted natural rubber
MAPE	Maleic anhydride-grafted-polyethylene
MAPP	Maleated polypropylene
MDPE	Medium density polyethylene
MMA	Methyl methacrylate
MMA-g-LR	Methyl methacrylate-grafted latex rubber
MMC	Metal matrix composites
MNR	Maleated natural rubber
MRPRA	Malaysian Rubber Producers' Research Association
MWNT	Multiwall carbon nanotubes
NaOH	Sodium hydroxide

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Nf	Recycled news pulp fiber
NR	Natural rubber
NRP	Natural rubber powder
OA	Oleic acid
PBS	Polybutylene succinate
PCBs	Printed circuit boards
Pf	Recycled kraft pulp fiber
Phr	Part per hundred resins
PLA	Poly (lactic acid)
PMC	Polymer matrix composites
PMMA	Poly (methyl methacrylate)
PP	Polypropylene
PVA	Poly (vinyl alcohol)
PVC	Poly (vinyl chloride)
RHDPE	Recycled high density polyethylene
RTR	Reclaimed tire rubber
SBC	Styrenic block copolymers
SEM	Scanning electron microscopy
SNR	Synthesized polystyrene-modified natural rubber

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T_d	Decomposition temperature
T_g	Glass transition temperature
TGA	Thermogravimetric analysis
TiO_2	Titanium dioxide
T_m	Melting temperature
TPE	Thermoplastic elastomer
TPNR	Thermoplastic natural rubber
TPO	Thermoplastic polyolefin elastomers
TPU	Thermoplastic polyurethane
TPV	Thermoplastic vulcanizates
UHMWPE	Ultra-high molecular weight polyethylene
VPP	Virgin isotactic polypropylene
WPC	Wood polymer composite

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Kesan Muatan Serat Bulu Ayam dan Modifikasi Kimia pada Komposit Polietilena Ketumpatan Tinggi Kitar Semula/Getah Asli/Serat Bulu Ayam

ABSTRAK

Komposit polietilena ketumpatan tinggi kitar semula/getah asli/serat bulu ayam (RHDPE/NR/CFF) telah disediakan menggunakan Brabender Plasticorder pada suhu 160˚C dan kelajuan rotor 50 rpm. Kesan kandungan CFF dan ejen gandingan ke atas sifat-sifat tegangan, sifat pembengkakan, morfologi, analisis spektroskopi inframerah (FTIR), pemeteran kalori pengimbasan kebezaan (DSC) dan analisis pemeteran graviti haba (TGA) komposit RHDPE/NR/CFF telah dikaji. Keputusan menunjukkan bahawa penambahan CFF telah mengurangkan kekuatan tegangan, pemanjangan pada takat putus dan darjah penghabluran, manakala modulus Young, peratus pembengkakan berat dan kestabilan terma komposit pula telah meningkat. Ejen gandingan seperti benzil urea dan ε-Kaprolaktam telah digunakan, dimana kesan positif pada sifat-sifat tegangan dan sifat pembengkakan komposit RHDPE/NR/CFF telah dihasilkan. Kehadiran benzil urea dan ε-Kaprolaktam telah meningkatkan kekuatan tegangan, modulus Young, dan kestabilan terma tetapi telah mengurangkan darjah penghabluran. Di samping itu, komposit RHDPE/NR/CFF juga telah dirawat menggunakan etanol dan metil metakrilat. Komposit RHDPE/NR/CFF dengan rawatan etanol mempunyai kekuatan tegangan, modulus Young, dan kestabilan terma yang lebih tinggi tetapi pemanjangan pada takat putus, peratus pembengkakan berat dan darjah penghabluran pula lebih rendah jika dibandingkan dengan komposit RHDPE/NR/CFF dengan rawatan metil metakrilat. Mikroskop penskanan elektron (SEM) permukaan patahan tegangan untuk komposit modifikasi kimia dengan benzil urea, ε-Kaprolaktam, etanol dan metil metakrilat menunjukkan bahawa interaksi antara muka di antara CFF dengan adunan RHDPE/NR adalah lebih baik dibandingkan dengan komposit kawalan RHDPE/NR/CFF.

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The Effect of Chicken Feather Fiber Loading and Chemical Modification of Recycled High Density Polyethylene/ Natural Rubber/ Chicken Feather Fiber Composites

ABSTRACT

Recycled high density polyethylene/ natural rubber/ chicken feather fiber (RHDPE/NR/CFF) composites had been prepared using Brabender Plasticorder at temperature 160˚C and rotor speed of 50 rpm. The effect of CFF content and coupling agent on tensil properties, swelling behavior, morphology, spectroscopy infrared (FTIR) analysis, differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) of RHDPE/NR/CFF composites were studied. The result showed that the addition of CFF reduced the tensile strength, elongation at break and degree of crystallinity, whereas the Young's modulus, weight swell percentage, and the thermal stability of composites increased. Coupling agent such as benzyl urea and ε-Caprolactam were used, which resulted in positive effect on mechanical properties, and swelling behavior of RHDPE/NR/CFF composites. The presence of benzyl urea and ε-Caprolactam, have increased the tensile strength, Young's modulus, and thermal stability but the degree of crystallinity decreased. In addition, RHDPE/NR/CFF composites were treated using ethanol and methyl methacrylate. The ethanol treated RHDPE/NR/CFF composites have higher tensile strength, Young's modulus, and thermal stability but lower elongation at break, weight swell percentage and the degree of crystallinity compared to the methyl methacrylate treated RHDPE/NR/CFF composites. The scanning electron microscopy (SEM) micrographs of tensile fracture surfaces for the composites with chemical modification of benzyl urea, ε-Caprolactam, ethanol and methyl methacrylate indicated that the interfacial interaction between CFF and RHDPE/NR blends were better than the control RHDPE/NR/CFF composites.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Thermoplastic elastomers (TPEs) are rubbery materials with an equivalent performance in terms of elasticity as the conventional thermoset rubbers. Due to the favorable manufacturing methods and environmental considerations, replacement of conventional vulcanized rubber by TPEs for industrial applications is growing rapidly.

The major advantage in some cases is that the middle range properties are better than those showed by either of the single materials. Moreover, some adjustments in terms of, cost, processing characteristics and durability are achievable through polymer blending. Thermoplastic elastomers (TPEs) can be fabricated from polymer blends made up of thermoplastic polymers, non-vulcanized rubber and vulcanized rubber (Nevatia et al., 2002). The resulting TPEs exhibit rubbery characteristics while retaining its thermo plasticity. The excellent properties of TPEs make them cover a wide range of applications in many industries, particularly in automotive industry such as body side moldings, interior skin and airbag covers. Other major applications are weather stripping, wire insulation, food wear and general mechanical goods such as hose and tube.

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In addition, the TPEs have a lot of commercial significance, which is fabricated without having vulcanization process, while available for reprocessing work to avoid the waste (Kahar et al., 2012). Among the various types of TPEs, the blending of natural rubber (NR) and polyolefin (Polyethylene) physically had caught respectable attention because of the uncomplicated preparation and less effort to achieve the needed technical properties. Furthermore, its environmental friendly approach has gain a lot of reputation since TPEs is recyclable. It has the potential to be recycled again and again without suffering losing the substantial properties (Grigoryeva et al., 2004).

Recycled polyethylene is the largest amount plastic manufactured in the world and extensively used polyolefin. Recycled polyethylene is produced in numerous polymeric forms, varying by their linearity and molecular weight, or branches, or presence of irregularities and many more. The density of the polymer is used as the principals classification features of polyethylene (Klyosov, 2007). Polyethylene exhibits a range of tensile strength and flexibilities, is generally tough, can be readily extruded or molded, and is relatively inexpensive. These characteristics guarantee that the various families of PE find major use as a commodity polymer.

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The post-consumer plastics recycling stays one of the desired recycling options for ecological and energy reasons, as long as it stays economically profitable. The recycled post-consumer plastics are low in cost, due to the rising number of plastic waste produced daily in large cities around the world. Furthermore, the post-consumer plastics recycling offer the solution for landfill problem. The municipalities are becoming more concerned about the increasing of plastic waste generation every year (increasing at 25% per year) when the landfill area only capable to increase at 7.5% per year. It is estimated that by 2015, there will be out of disposal options for plastic waste.

High density polyethylene (HDPE) is a famous plastic type due to its versatility, having a wide range of applications such as consumer goods, containers and furniture. Post-consumer HDPE from bottles is a fascinating source of recycled material because, on one hand, it cannot be used again in alimentary applications and, on the other hand, its high melting viscosity makes direct transformation via injection moulding very difficult. Recycled HDPE can be used in an increasing amount of potential applications, as long as the mechanical, impact, and thermal properties of the material (recycled-virgin) is not far from each other (Maspoch et al., 2005).

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Natural rubber (NR) is an elastomer acquired from rubber tree latex that consist of 93–95% cis-1, 4-polyisoprene. NR has various outstanding properties, such as high strength, superior resilience, and good processability. The good properties, especially resilience, play an important role among other elastomers (Harper, 2000). The applications of NR include automotive tire, tire tread, gloves, and mechanical goods.

Polymer composites are the combinations of materials consisting reinforcing phase (fibers, particles or sheets) and the matrix phase (polymer, ceramic or metal). Leading elements in a fiber-reinforced composite material are the matrix and reinforcing fibers. The main idea of filler into the composites is to improve certain properties and lower the cost of the composites (Manchado & Arroyo, 2002).

Proper decision of the fiber length, fiber type, fiber orientation and fiber volume fraction is very crucial, since it influences the density, cost, and the composite properties such as tensile properties (Cao et al., 2012), thermal properties (Singha & Thakur, 2009), mass swell resistance (Abu Bakar et al., 2010). The strength and the stiffness of the composites are influenced by disorientation of fibers, fibers of nonuniform strength, discontinuous fibers, Interfacial conditions and the residual stresses. For example, composites strength and stiffness will be reduced when the fibers are not parallel to the loading direction.

The application of natural fibers for the composites reinforcement has caught growing attention. It holds many significant rewards over synthetic fibers (Begum & Islam, 2013). At this moment, numerous types of natural fibers have been studied for use in composites such as jute straw (Liu & Dai, 2007), hemp (Placet et al., 2012), flax (Bourmaud et al., 2013), rice husk (Ndazi et al., 2007), wood (Coutinho & Costa, 1999), wheat (Panthapulakkal et al., 2006), sugarcane (Lu et al., 2006), grass (De et al., 2004), kenaf (Feng et al., 2001), ramie (Goda et al., 2003), reeds (Han et al., 2001), sisal (Nair et al., 2000), coir (Rout et al., 2001), water hyacinth (A. G. Supri & Lim, 2009), kapok (G. V. Reddy et al., 2008), banana fiber (Pothan et al., 2003), pineapple leaf fiber (J. George et al., 1997) and papyrus (Nishino et al., 2007).

Natural fibers are extensively separated into three classes depending on their source: animal based, plant based, and mineral based. Plant-based fibers are ligno-cellulosic in nature consisted of lignin, hemicellulose and cellulose. On the other hand, animal based fibers are of proteins such as wool and silk. Generally, a mineral based composite is asbestos fiber and is only a naturally occurring mineral fiber (silicate based mineral). Natural fiber-reinforced polymer composites have captivated many research pursuits due to their possibility to replace synthetic fiber composites such as carbon or glass fiber composites (Bledzki & Gassan, 1999). This happens because of natural fibers exceed synthetic fibers in term of less damage to processing equipment, lower weight, lower cost, good relative mechanical properties, better surface finish of moulded parts composite and renewable resources (Corbiere-Nicollier et al., 2001; Joshi et al., 2004). However, despite the potential of replacing the synthetic fibers, natural fibers do have

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some problems at high fiber content due to the fiber-fiber interaction and fiber dispersion problems.

Many researchers reported that the mechanical properties for polymer composites reinforced with natural fiber are largely dependent on the matrix-fiber interface adhesion (Chin & Yousif, 2009; Rosa et al., 2009). This is primarily because natural fibers are abundant in hemicellulose, celluloses, lignin and pectin, which are hydroxyl groups. Natural fibers have the tendency to be hydrophilic and strong polar materials while polymers are hydrophobic. As a result, there are obvious problems of the matrix-fiber incompatibility, which weakens natural fiber-matrix interface area. However, many researchers suggested that chemical treatments namely alkali, acetylation, and bleaching treatment may enhance the interfacial adhesion between the matrix and the fiber (Alawar et al., 2009; Cantero et al., 2003; Haque et al., 2009; Hepworth et al., 2000; Saha et al., 2010). These chemical treatments clean the fibers surface from impurities thus increases the fiber surface roughness and interrupting the moisture absorption process by withdrawing the OH groups in fiber (Shalwan & Yousif, 2013).

ε-Caprolactam ($C_6H_{11}NO$, CPL) is used as a coupling agent in this research. It is a popular industrial organic chemical material that is used widely in the manufacture of polyamide engineering plastics and fiber. The final product properties depend on the purity of ε-Caprolactam. Water is widely occurring impurity in ε-Caprolactam, and it is usually eliminated by distillation. ε-Caprolactam is heat-sensitive substance, thus, the triple-effect evaporation process is widely used in the manufacture of high-quality caprolactam (Lin et al., 2012). Recently, Zhu et al. (2010) and Li et al. (2010) synthesized crosslinked PVA and other polymer membranes for the PV separation of CPL-water solution. The researchers reported that the decreasing crystallinity of the membrane's active layer will increased the flux.

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