RHEOLOGICAL, MECHANICAL, MORPHOLOGICAL AND THERMAL PROPERTIES OF RECYCLED POLY (ETHYLENE TEREPHTHALATE)-POLYETHYLENE FILLED MONTMORILLONITE

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Special dedications to my beloved wife and parents…
Thanks for the love and memories

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ABSTRACT

The objective of this research is to investigate the effect of incorporating nanofiller, montmorillonite (MMT) on mechanical, morphology, rheological and thermal properties of recycled poly(ethylene terephthalate) (rPET) and High density polyethylene (HDPE) nanocomposites. The MMT contents in 90:10 rPET/HDPE and 70:30 rPET/PE ranged from 1 to 5 wt.%. Blends based on rPET/HDPE nanocomposites were made through single extrusion and injection-molded into tensile and impact test samples. Samples underwent rheological test by using capillary rheometer, and the morphology of the nanocomposites was investigated by scanning electron microscopy (SEM). Thermal stability of organoclays and nanocomposites was tested by thermogravimetric analysis (TGA). The results pointed out that MMT displayed a higher compatibilizing act giving rise to a neat improvement of phase dispersion and interfacial adhesion in the blends. The maximum tensile strength was at 3 wt. % and 1 wt. % of MMT for 90:10 and 70:30 rPET/HDPE blends. However, tensile modulus decreased significantly with the incorporation of MMT. Impact strength for both blending 90:10 and 70:30 reached a maximum point at 3 wt. % and started to decrease beyond 3 wt. %. The incorporation of MMT increased the shear viscosity of 90:10 and 70:30 which reached a maximum value at 3 wt. % and 1 wt. %.

ABSTRAK

Objektif penyelidikan ini adalah untuk mengkaji kesan penambahan pengisi nano montmorilonite (MMT) terhadap pencirian morfologi, mekanikal, sifat reologi dan terma komposit bersaiz nano poli(etilena terephthalate) kitar semula (rPET) dan polietilena berketumpatan tinggi (HDPE). Komposisi komposit bersaiz nano dibahagikan kepada 90:10 dan 70:30 rPET/HDPE dengan kesan penambahan MMT dari 1 hingga 5 wt%. Komposisi komposit nano rPET/HDPE telah disediakan menggunakan mesin penyemperit berskru tunggal berpenyebati nano dan mesin acuan penyuntikan bagi membentuk sampel untuk ujian kekuatan regangan dan kekuatan hentaman. Ujian reologi dijalankan menggunakan reometer kapilari serta ciri-ciri morfologi komposit nano dilakukan menggunakan mikroskopi pengimbasan elektron (SEM). Kestabilan terma pengisi nano MMT dan komposit nano telah diuji menggunakan alat analisis termogravimetri (TGA). Keputusan menunjukkan penambahan MMT mampu menyumbang peningkatan kebolehserakan fasa dan lekatan antara muka komposit. Kekuatan regangan maksima bagi komposisi komposit bersaiz nano 90:10 dan 70:30 rPET/HDPE dengan penambahan MMT adalah pada 3 wt. % dan 1 wt. %. Modulus regangan menurun secara ketara dengan penambahan MMT. Kekuatan hentaman kedua-dua komposisi komposit bersaiz nano 90:10 dan 70:30 mencapai nilai maksima pada penambahan MMT sebanyak 3 wt. % tetapi berkurang apabila melebihi 3 wt. %. MMT meningkat kelikatan ricih 90:10 dan 70:30 dengan mencapai nilai maksima pada penambahan 3 wt. % dan 1 wt. %.

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LIST OF ABBREVIATIONS

ASTM	-	American Standard of Testing and Method
CO_2	-	Carbon Dioxide
DSC	-	Differential Scanning Calorimetry
E-GMA	-	ethylene-glycidyl methacrylate copolymer
EMAA	-	ethylene-methacrylic acid random copolymer
EVOH	-	Ethylene vinyl alcohol
G'	-	Storage Modulus
HDPE	-	High density polyethylene
HDT	-	Heat Deflection Temperature
HDXLPE	-	High density cross-linked polyethylene
HMWPE	-	High molecular weight polyethylene
IUPAC	-	International Union of Pure and Applied Chemistry
LDPE	-	Low density polyethylene
LLDPE	-	Linear low density polyethylene
MDPE	-	Medium density polyethylene
MMT	-	Montmorillonite
MMT-IM	-	MMT treated with 1,2-dimethyl-3-octadecyl-1H-imidazol-3 -ium chloride
MMT-IME	-	MMT treated with [3-(glycidyloxy)propyl] trimethoxysilane
MFI	-	Melt Flow Indexer
MT	-	Metric Tonne
PE	-	Polyethylene
PEAL	-	polyethylene and aluminium
PE-g-MAH	-	Polyethylene grafted with maleic anhydride

PET	-	Poly (ethylene terephthalate)
PETE	-	Poly (ethylene terephthalate)
PRS	-	PET-Recycling Switzerland
rPET-PE	-	recycled PET-Polyolefin
SEM	-	Scanning Electron Microscopy
TGA	-	Thermal Gravimetric Analysis
T_g	-	Glass Transition Temperature
T_c	-	Crystalline Temperature
T_m	-	Melting Temperature
UHMWPE	-	Ultra high molecular weight polyethylene
ULMWPE	-	Ultra low molecular weight polyethylene
USA	-	United States of America
VLDPE	-	Very low density polyethylene
X_c	-	Crystalline Fraction
XLPE	-	Cross-linked polyethylene

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Poly (ethylene terephthalate) (PET) is the most major post consumer plastics wastes, following with polyethylene, polypropylene, polystyrene and polyvinyl cloride (Lin, 1998). In 2009, PET consumption was about 8% from the total of global polymer demand equal to 176 million MT overall (Plasticsnews, 2010). In Malaysia trend, the analysis has been done by Nexant ChemSystems and was highlighted in RMK-10 has shown the consumption about 20% of 2.6 million MT was contributed by PET. It was the second largest consumption after HDPE percentage in 2010 and expected to continue among the major polymer applications in Malaysia.

Desired final properties with desires specific purposes that are influenced by the processing parameter must be understood and this fundamental is the key to produce of new materials. Therefore, incorporation of the polymer with organoclay to nanocomposites will be the option to overcome their properties enhancement concern (Takekoshi *et al.*, 1996). The blends system of recycled PET-Polyolefin, rPET/HDPE is mostly preferred because of its low cost and the resistances of polyolefin in contributing to high temperatures of processes needed for PET approximately between 230°C to 270°C under suitable conditions. High density Polyethylene, HDPE is one of the solutions to overcome the mechanical properties weaknesses of rPET. Because of its low glass transition temperature, it may have good performance as impact modifier to increase the impact strength of rPET. Blending postconsumer polymers can become an alternative solution to introduce a better properties and to broad the application potential of recycled plastics.

In this research, the effects of nanoclay and concentration, on the rheological and physical properties of rPET were investigated. There are very limited research had been published on recycled PET/clay nanocomposites regarding on the preparation and characterization (Pegoretti *et al.*, 2004). This future work aim is to provide guidelines for the rPET-based nanocomposites compounding with HDPE and organoclay. A scrapped PET sheet was used and the effects of organoclay addition on rheological properties of rPET/HDPE were investigated to enhance PET recycling recovery as the goal. Beside, mechanical tests were performed for characterizing the nanocomposites. The morphology was analyzed by Scanning Electron Microscopy (SEM) in order to study the extent of filler dispersed in the matrix. Thermogravimetric Analyzer (TGA) was used to study the thermal stability of the nanocomposites.

1.2 Problem Statement

PET represents one of the most successful and widespread examples of polymer recycling, mostly in the drinking bottles industry which has made PET the main target for plastic recycling. The way to ensure the rPET is ready to be used as virgin demands, the tailor-made of the enhanced properties should be achieved to overcome the drawbacks prior to the applications.

The research of rPET blended HDPE with MMT were answered several of problems.

a) Does HDPE will be able to increase the impact resistance of rPET due to it incorporation?

b) Does the addition of MMT will result the great contribution to rheological and mechanical strength by this blending?

c) Does the MMT will probably help to improve the compatibility of rPET and HDPE?

1.3 Objective of Study

The objective of this study is to enhance the properties of rPET to become more stable in recycling process particularly, in the beverage industry which is the major of PET application as a drinking bottle for consumer. In this research, scrap of PET sheets was for blending with HDPE and the addition of organoclay, MMT was used as filler. Through this, the rPET/HDPE nanocomposites will be utilised into the packaging manufacturing.

Three objectives of this investigation are,

a) To identify the effect of HDPE composition rPET/HDPE nanocomposites on rheological, mechanical and thermal stability of the nanocomposites.

b) To investigate the effect of organoclay on the rheological properties, mechanical, morphological and thermal stability of rPET/HDPE nanocomposites.

c) To study the effect of MMT into rPET/HDPE matrix for enhancement through morphology.

1.4 Scope of Study

i) Literature review

Elaboration of the current research and development trend of recycled PET/HDPE/MMT and related to the objective of the research study.

Sample preparation

ii) Preparation and treatment of rPET

- The sheets were washed, dried and crushed into a small flakes size before it ready to use.

iii) Preparation of rPET/HDPE nanocomposites

a) The rPET/HDPE/MMT was prepared by melt blending method with single screw extruder.

b) Injection moulding was for producing of testing sample for mechanical testing.

iv) Mechanical properties analysis

a) Tensile test by using an Instron equipment.
   - To determine the elastic modulus and elongation of specimen

b) Izod Impact test by using Toyoseiki impact machine.
   - To determine the impact strength of the nanocomposites

v) Rheological properties study by using capillary rheometer Gottfert Rheograph 2003.

-Capillary Rheometer – to determine the shear rate, shear stress and viscosity

vi) Morphology study by using SEM type JEOL JSM-6390 LV.

-Scanning Electron Microscopy (SEM) – to determine the surface and structure of specimen.

vii) Thermal properties study by using Perkin-Elmer TGA-7 instrument.

-Thermogravimetric Analysis (TGA)

-to determine the degradation of specimen

vii) Report Writing

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