Faculty of Engineering

INVESTIGATION OF PHYSICO-MECHANICAL, THERMAL, DYNAMIC MECHANICAL, MORPHOLOGICAL AND OPTICAL PROPERTIES ON LOW DENSITY POLYETHYLENE/SILICA AND POLYPROPYLENE/CLAY NANOCOMPOSITES

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Bachelor of Engineering with Honours

(Chemical Engineering)

2017

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Final Year Project Report	√
Masters	
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26 May 2017
Date

INVESTIGATION ON PHYSICO-MECHANICAL, THERMAL, DYNAMIC MECHANICAL, MORPHOLOGICAL AND OPTICAL PROPERTIES ON LOW DENSITY POLYETHYLENE/SILICA AND POLYPROPYLENE/CLAY NANOCOMPOSITES

BRANDON KA JEN HAU

A dissertation submitted in partial fulfilment
of the requirement for the degree of
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Dedicated to my beloved parents and my family who always bestow me sustainable motivations and encouragements

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ABSTRACT

Recently, polymer nanocomposites have received increasing research interest due to their superior properties as compared with other conventional composites. Thus, these superior properties of polymer nanocomposites can be achieved by introducing the nanoparticles or nanofillers into it. In this study, inorganic nanofillers such as fumed silica and nanoclay were used as reinforcing agents for the preparation of polymer nanocomposites. Fumed silica was introduced into the low-density polyethylene in order to produced polyethylene based nanocomposite while nanoclay was introduced into polypropylene as to produce polypropylene based nanocomposite. Both polyethylene and polypropylene based nanocomposites were prepared through direct melting method which this method is considered environmental friendly due to the reason of substances like organic solvents, organic surfactants and several specific chemical substances are not being used in this method. Physical and morphological properties of the nanocomposites were tested using Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) testing. Tensile testing was carried out in order to observe the mechanical properties of the nanocomposites. Other testing like Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) also were carried out in order to study the electrical and thermal properties of the nanocomposites. Both silica/low-density polyethylene and nanoclay/polypropylene nanocomposites showed enhanced tensile strength and modulus of elasticity as compared to pure low-density polyethylene and polypropylene. FTIR confirmed the presence of silica and nanoclay in the nanocomposites which these nanofillers help to improve the surface roughness and reduce the void fraction. SEM analysis proved that silica and nanocly based nanocomposites exhibited improved water uptake resistance comparing to the pure polymers. Both TGA and DSC tests showed that the addition of nanofillers like silica and nanoclay is able to enhance the thermal stability and heat resistance of both silica and nanoclay based nanocomposites.

ABSTRAK

Baru-baru ini, nanokomposit polimer telah menunjukkan peningkatan minat dalam kalangan penyelidikan disebabkan oleh sifat-sifat unggul mereka berbanding komposit konvensional lain. Oleh itu, sifat-sifat unggul nanocomposites polimer boleh dicapai dengan memperkenalkan nanopartikel atau nanofillers ke dalamnya. Dalam kajian ini, nanofillers bukan organik seperti silika marah akibat dan nanoclay telah digunakan sebagai mengukuhkan ejen untuk penyediaan nanocomposites polimer. Silika telah diperkenalkan ke dalam polietilena berketumpatan rendah untuk menghasilkan nanokomposit berasaskan polietilena manakala nanoclay telah diperkenalkan ke polypropylene untuk menghasilkan nanokomposit berasaskan polipropilena. Kedua-dua nanocomposites berdasarkan polietilena dan polipropilena telah disediakan melalui kaedah lebur langsung dan kaedah ini dianggap mesra alam kerana sebab bahan-bahan seperti pelarut organik, surfaktan organik dan beberapa bahan kimia tertentu tidak digunakan dalam kaedah ini. Sifat-sifat fizikal dan morfologi daripada nanocomposites telah diuji menggunakan Fourier Transform Infrared Spektroskopi (FTIR) dan ujian Scanning Electron Microscopy (SEM). Ujian tegangan telah dijalankan untuk melihat sifat-sifat mekanik yang nanocomposites. Ujian lain seperti analisis Termogravimetri (TGA) dan Perbezaan Imbasan Calorimetry (DSC) juga telah dijalankan untuk mengkaji sifat-sifat elektrik dan haba daripada nanocomposites. Kedua-dua silika/polietilena berketumpatan rendah dan nanokomposit nanoclay/polypropylene menunjukkan kenaikan kekuatan tegangan dan modulus keanjalan berbanding polietilena berketumpatan rendah tulen dan polipropilena. FTIR mengesahkan kehadiran silika dan nanoclay dalam nanocomposites yang nanofillers ini membantu untuk meningkatkan kekasaran permukaan dan mengurangkan pecahan kekosongan. Analisis SEM membuktikan bahawa silika dan nanokomposit nanocly berdasarkan dipamerkan lebih baik rintangan pengambilan air berbanding dengan polimer tulen. Kedua-dua TGA dan ujian DSC menunjukkan bahawa penambahan nanofillers seperti silika dan nanoclay mampu meningkatkan kestabilan terma dan rintangan haba kedua-dua silika dan nanoclay nanocomposites berasaskan.

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NOMENCLATURE

°C	:	Degree Celsius
GPa	:	Gigapascal
g	:	Gram
J	:	Joule
MPa	:	Megapascal
μm	:	Micrometer
nm	:	Nanometer
%	:	Percent
cm^{-1}	:	Per centimetre
rpm	:	Revolution per minute
wt%	:	Weight percentage

ABBREVIATIONS

AIBN	:	Azo bis isobutyronitrile
BPO	:	Benzoyl peroxide
CMCs	:	Ceramic matrix composites
DSC		Differential Scanning Calorimetry
EVA	:	Ethylene-vinyl-acetate
FTIR	:	Fourier transform infrared spectroscopy
HDPE	:	High density polyethylene
HMW HDPE	:	High molecular weight high density polyethylene
LDPE	:	Low-density polyethylene
LLDPE	:	Linear low-density polyethylene
MDPE	:	Medium density polyethylene
MMCs	:	Metal matrix composites
MMT	:	Montmorillonite
PAs	:	Polyamides
PAI	:	Polyamide-imide
PE	:	Polyethylene
PEK	:	Polyetherketone
PMA	:	Perpendicular magnetic anisotropy
PMCs	:	Polymer matrix composites

PP	:	Polypropylene
PVC	:	Polyvinyl chloride
rpm	:	Revolution per Minute
SEM	:	Scanning electron microscopy
TGA	:	Thermogravimetric analysis
T_g	:	Glass transition temperature
T_m	:	Melting temperature
UP	:	Unsaturated polyester
VLDPE	:	Very low-density polyethylene
Al_2O_3	:	Aluminium oxide
$Al(OH)_3$	:	Aluminium trihydroxide
Fe_3O_4	:	Iron oxide
$Mg(OH)_2$	:	Magnesium hydroxide
SiO_2	:	Silica oxide
Sb_2O_3	:	Antimony trioxide
TiO_2	:	Aluminium Trioxide

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The commercial importance of polymers has led to intense applications in composites form in several fields like aerospace, automotive, marine, infrastructure, military, and so on (Barus et al., 2009). In recent years, nanocomposites have caught the attention of scientists' due to the improved mechanical, thermal, solvent resistance and fire-retardant properties of nanocomposites as compared to the pure or traditional composites materials. The addition of inorganic nanoparticles such as silica, titania, carbon nanotubes, layer silicates and others inorganic nanoparticles into the polymeric matrices can actually modify their properties.

Nanotechnology has been recognized as one of the highly expectation areas for the technological development in 21th century. The particles which having a small size in the range from a few to several tens of nanometers are known as quasi zero-dimensionalmesoscopic system, quantum dots, quantized or Qparticles, and so on (Sharma, et al., 2004). Also, Jordan et al. (2005) states that the nano-sized inclusions are referred to the small particles that have at least one dimension about the range of 1 to 100nm. Nanofillers that are with a low concentration are able to provide an improvement of relevant properties of the nanocomposites like increased modulus and strength, transparency, decrease of gas permeability, increased scratch, abrasion, resistance toward heat and solvent and decreased flammability (Hussain et al., 2006). The nature of the filler and polymer matrix interface has been used to divide these materials into two distinguishable classes which in the first class (Class I), there are only weak bonds like hydrogen, van der Waals or $\pi - \pi$ bonds between both of the matrix and fillers while in the second class (Class II), the two phases are linked together via the strong chemical bonds like covalent and ionic bonds (Sanchez et al., 2005).

According to Denault and Labrecque (2004), polymer nanocomposites or in short PNC are defined as the polymers like thermoplastics, thermosets or elastomers that have been reinforced with tiny quantities (less than 5% by weight) of nano-sized particles which having high aspect ratios (L/h more than 300). The properties of the nanocomposites produced are deeply depending on the types of inorganic materials that are existed in the polymer matrix (Ching et al., 2012; Lagashetty and Venkataraman, 2005; Chee et al., 2010; Li et al., 2011). Plus, the efficiency of the reinforcing fillers in the polymer matrix is inversely proportional to the filler size used and proportional to the ratio blend in the polymer matrix (Ching et al., 2012).

1.2 Problem Statement

Polyethylene (PE) is one of the most widely used thermoplastic polymers as this type of thermoplastic polymer acquires some unique properties such as high chemical resistance and relatively good mechanical properties. Plus, polyethylene also is considered cheap as well. Besides that, polypropylene (PP) is one of the most widely used polyolefins and this type of polymer does not consist of any polar group in its backbone (Perez et al., 2010). Polypropylene is a versatile polymer which this type of polymer is widely used in textiles and packaging. Recently, polymer nanocomposites have received increasing research interest due to their superior properties as compare with the conventional composites. The improvements in mechanical properties like stiffness and toughness, dimensional and thermal properties could be achieved by using the nanofillers as the reinforcing agents on the composites. Thus, the effect of using the fumed silica and nanoclay as the reinforcing agents on low density polyethylene and polypropylene will be studied and investigated in this research.

1.3 Research Aim and Objectives

This study was studied to synthesize and improve the physical, mechanical, morphological, and optical properties of both polyethylene-based and polypropylene-based nanocomposites by using the fumed silica and nanoclay nanofillers as the reinforcing agents. The objectives of this research are listed below:

i. To synthesize polyethylene/silica and polypropylene/clay nanocomposites.
ii. To investigate the mechanical, morphological, optical and thermal properties of the synthesized nanocomposites.

1.4 Scope of Study

The scope of this study is mainly focusing on the effect of the fumed silica and nanoclay loading on the physical, mechanical, morphological, and optical properties of the polyethylene-based and polypropylene-based nanocomposites. Both loading of the nanofillers were manipulated in order to investigate the optimum loading composition in both polyethylene-based and polypropylene-based nanocomposites. Besides that, the factors that will affect the uniform dispersion of the nanofillers into polyethylene and polypropylene were studied. Lastly, the comparison between both of the polyethylene-based and polypropylene-based nanocomposites and the conventional composite material was made.

1.5 Expected Outcomes of the Research

The physical, mechanical, morphological, and optical properties of the polyethylene-based composite will be further improved by the addition of fumed silica nanofiller as the reinforcing agents. Plus, the physical, mechanical, morphological, and optical properties of polypropylene-based nanocomposite also will be enhanced by the addition of nanoclay nanofiller as the reinforcing agents.

`1.6 Overview of thesis

The Gantt chart for this study is prepared and attached in **APPENDIX A**. There are five main chapters are included in this study which are:

Chapter 1 gives a brief understanding and description about the most widely used thermoplastics such as polyethylene and polypropylene are introduced with different nanofiller or nanoparticles like fumed silica and nanoclay in this study in order to prepare polymer nanocomposites. This chapter also comprised of background of study, problem statement, research objectives, scope of study and also the expected outcome of this study.

Chapter 2 discuss about the literature review that is related to the title of this study. Detail introduction of both polyethylene and polypropylene as well as the nanofillers used in this study is included in this chapter. Lastly, this chapter also discussed about the general methods used for the preparation of nanocomposites.

Chapter 3 includes the methodology used for the preparation of both polyethylene and polypropylene based nanocomposites of this study. Main materials and equipment that are used in this study are included in this chapter. Plus, equipment used for determining the characterization of the nanocomposites produced are discussed in this chapter as well.

Chapter 4 basically discuss the results obtained from different testing which is done based on the nanocomposites produced in this study. Examples testing used for identify or determine the characterization of the nanocomposites include tensile strength testing, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC).

Chapter 5 concludes all the results and finding obtained from the testing done in the previous chapter. This chapter also concludes the hardships encounter in this study and constructive recommendation for the future improvement.

1.7 Summary

In this chapter, the background of study of this research, problem statement, research objectives, scope of the study and the expected outcome are discussed. Both polyethylene and polypropylene are the polymers which are widely used for many applications. However, the properties of both of these polymers can be further enhanced by introducing the nanofillers into these two polymers. Fumed silica nanofiller is used as the reinforcing agent for polyethylene while nanoclay nanofiller is used as the reinforcing agent for polypropylene.