CHARACTERIZATION AND PROPERTIES OF RECYCLED POLYPROPYLENE (rPP) / RECYCLED HIGH DENSITY POLYETHYLENE (rHDPE) BLENDS AND ITS COMPOSITES

by

SITI MARIAM ATIQAH BINTI ABDUL AZIZ
(1330410938)

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School of Materials Engineering

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LIST OF ABBREVIATIONS AND SYMBOLS

ASTM	American Society for Testing of Materials
ATR	Attenuated total reflectance
CO_2	Carbon dioxide
DSC	Differential scanning calorimetry
FTIR	Fourier-transform infrared analysis
HDPE	High density polyethylene
MAPP	Maleic anhydride grafted polypropylene
php	Part per hundred polymer
PP	Polypropylene
PE	Polyethylene
SEM	Scanning electron microscopy
T_m	Melting temperature
TGA	Thermogravimetric analysis
ΔH_e	Enthalpy of experimental
ΔH_t	Enthalpy of theoretical
X_c	Degree of crystallinity

Pencirian dan Sifat Adunan dan Komposit Polipropilena Kitar Semula (PKS)/ Polietilena Ketumpatan Tinggi Kitar Semula (PEKTKS)

ABSTRAK

Adunan termoplastik polipropilena kitar semula (PKS) dan Polietilena Ketumpatan Tinggi Kitar Semula (PEKTKS) telah dikaji. Adunan-adunan PKS dan PEKTKS telah disediakan menggunakan ekstruder skru berkembar pada suhu 190°C dan kelajuan rotor pada 180 rpm. Kesan nisbah adunan-adunan ke atas sifat- sifat tensil, morfologi dan sifat-sifat terma juga telah dikaji. Didapati bahawa dengan peningkatan kandungan PEKTKS di dalam adunan-adunan PKS/PEKTKS, telah mengurangkan kekuatan tensil, elastisiti modulus manakala pemanjangan pada takat putus meningkat. Penghabluran dan kestabilan terma adunan-adunan meningkat dengan peningkatan kandungan PEKTKS. Morfologi adunan-adunan PKS/PEKTKS menunjukan permukaan patahan tensil adalah kasar bersama peningkatan kandungan PEKTKS. Pengserasi, maleik anhidrida polipropilena (MAPP) telah digunakan untuk meningkatkan sifat-sifat tensil. Penambahan MAPP telah meningkatkan kekuatan tensil, elastisiti modulus, penghabluran dan kestabilan terma tetapi mengurangkan pemanjangan pada takat putus. SEM mikrograf pada permukaan patahan tensil adunan-adunan PKS/PEKTKS dengan MAPP menunjukkan peningkatan interaksi antaramuka dan lekatan antara PKS dan PEKTKS. Penambahan kaolin sebagai bahan pengisi telah menunjukkan perubahan ketara pada sifat adunan PKS/PEKTKS/kaolin. Pada kandungan 10 bsp kaolin kekuatan tensil dan elastisiti modulus menunjukkan nilai optimum. Penambahan kaolin telah meningkatkan kestabilan terma komposit PKS/PEKTKS/kaolin dan penghabluran PKS manakala penghabluran PKTKS menunjukkan pengurangan. Penyerapan air komposit PKS/PEKTKS meningkat dengan peningkatan kandungan kaolin. Kehadiran MAPP di dalam komposit PKS/PEKTKS/kaolin telah menunjukkan sifat-sifat tensil yang lebih tinggi dibandingkan komposit tanpa MAPP. Komposit dengan MAPP mempunyai rintangan yang baik terhadap keserapan air berbanding komposit tanpa MAPP. Penghabluran dan kestabilan terma komposit dengan MAPP adalah lebih tinggi berbanding komposit tanpa MAPP. Peningkatan interaksi antaramuka antara PKS/PEKTKS dengan kaolin dengan kehadiran MAPP telah dibuktikan dengan kajian SEM.

Characterization and Properties of Recycled Polypropylene (rPP)/ Recycled High Density Polyethylene (rHDPE) Blends and Its Composites

ABSTRACT

The thermoplastic blends of recycled polypropylene (rPP) and recycled high density polyethylene (rHDPE) was studied. The rPP/rHDPE blends were prepared by using twin screw extruder at temperature 190°C and rotor speed of 180 rpm. The effect of blend ratio on tensile properties, morphology and thermal properties were investigated. It was found that the increasing in rHDPE content of rPP/rHDPE blends have decreased the tensile strength, modulus of elasticity but increased in the elongation at break. The crystallinity and thermal stability of blends increased with increasing rHDPE content. The morphology of rPP/rHDPE blends showed rHDPE was dispersed in the rPP continuous phase with increasing rHDPE content. The compatibilizer, maleic anhydride grafted polypropylene (MAPP) was used to enhance tensile properties of the blends. The addition of MAPP has improved the tensile strength, modulus of elasticity, crystallinity of blends and thermal stability but lower the elongation at break. The micrograph SEM of tensile fracture surface of rPP/rHDPE blends with MAPP showed enhanced interfacial interaction and adhesion between rPP and rHDPE due to the reduction of rHDE dispersed phase. The addition of kaolin as filler has led to significant changes to the rPP/rHDPE blends properties. At 10 php of kaolin content, the tensile strength and modulus of elasticity showed optimum values. The incorporation of kaolin has increased the thermal stability of rPP/rHDPE/kaolin composites and the crystallinity of rPP, and rHDPE components was reduced. The water absorption of rPP/rHDPE/kaolin increased with increasing kaolin content. The presence of MAPP in rPP/rHDPE/kaolin composites exhibit higher tensile properties of the composites compared to composites without MAPP. The composites with MAPP have better water resistance compared to composites without MAPP. The crystallinity and thermal stability of composites with MAPP were higher than composites without MAPP. The improvement of interfacial-interaction with rPP/rHDPE and kaolin with the presence of MAPP was proven by SEM studied.

CHAPTER 1

INTRODUCTION

1.1 Research background

Nowadays, over 95 million tons of plastic materials have been consumed for the past few decades. Plastics have been widely used in automotive and industrial applications, packaging, flood prevention, soil conservation and construction (Sukunya et al, 2007). Polyolefin, such as polyethylene (PE) and polypropylene (PP) are the most widely used thermoplastic in the world. The availability of plastic applications has contributed to increment of solid waste stream volume (Rahman et al., 2012). Consequently, the amount of plastic consumption has resulted in increasing amount of waste plastic being generated which can lead to waste disposal crisis (Evelin et al., 2000). Due to its hazardous effect to the environment and the slow degradation of plastic, it is crucial to determine suitable solution for these plastic wastes.

The conventional methods of managing the waste of plastics were by landfill, incineration and recycling (Al-Salem et al., 2009). Plastic wastes disposal to landfill and by incineration has become less desirable because of increasing society awareness towards the environment sustainability and the arising cost as well as the poor biodegradability of polymers (Rajendran et al., 2012). Therefore the only method to manage plastic waste towards sustainability is recycling; either mechanical or chemical recycling (Rahman et al., Rajendran et al., 2012). For the past 10 years, plastic recycling has received substantial attention as well as the growth of environmental concerns about the waste plastic disposal and the potential economic benefits of using recycled plastic. The ability to preserve energy and carbon dioxide (CO_2) by avoiding the oil extraction process and landfill reduction has become the advantages of using recycled plastic products (Rajendran et al., 2012). The recycling of waste plastic is able to reduce the demand for virgin plastic which made from petroleum-based sources such as high-density polyethylene (HDPE) and polypropylene (PP) (Evelin et al., 2000).

Polypropylene (PP) has excellent mechanical, physical and thermal properties which made PP better choice for room-temperature applications. PP is stiff and has high melting point, low density and excellent chemical resistance (Salih et al., 2012). High density polyethylene (HDPE) which was prepared from ethylene through a catalytic polymerization has good chemical resistance and excellent resistance in environmental stress-cracking (Paul et al., 2001). HDPE and PP are nearly not degraded in the natural environment although being exposed for a long period of time (Vranjes et al., 2007). The slow degradation properties of these plastic cause a waste disposal crisis for environment and hence gives off plastic wastes since it is consist mainly of HDPE and PP (Achilass et al., 2008). The conversion of these plastic wastes from polymer into monomers and complete sorting would involve higher processing cost (Vranjes et al., 2007).

The recycling plastic waste can be done by blending these plastic wastes which could greatly increase the properties of the blends (Kukaleva et al., 2000a). Polymer blending is an efficient way in developing new materials with improved properties while maintaining the main properties of the materials at lower cost (Ultracki, 2003). Blending two chemically different polymers is a crucial method in industrial production for amending product with optimum properties and the performance of the polymer blends depend on the properties of the polymeric components (Sani et al., 2006). Over the years, the polypropylene (PP) and polyethylene (PE) blends research have received outstanding concern due to the properties of PP which has low impact strength at low temperature and poor environmental stress cracking resistance. Thus, the blends of PP and PE have been developed in order to enhance the processing and properties of PP as an engineering plastic (Li et al., 2001a). Some studies by Li et al., (2003) have been reported the blends of PP with very low density polyethylene (VLDPE), linear low density polyethylene (LLDPE) and ultra low density polyethylene (ULDPE). Blends of PP/HDPE showed lower mechanical properties and the morphology images of the blends indicated that the adhesion between PP and HDPE was weak (Chen et al., 2007). Strapasson et al., (2005) have studied the PP/LDPE blends and they reported that there were increasing in the elastic modulus and yield strength with the addition of LDPE at 25%. According to the study done by Fang et al., (2013) blends of waste PE/PP, the mechanical strength tend to improve with increasing amount of waste PP in the blends.

However, PP and PE blends exhibited immiscibility in their blends which leads to poor adhesion among the blends phases, coarse morphology and consequently, poor mechanical properties. Various studies have been suggested to overcome and to enhance the interfacial adhesion of the immiscibility of PP/PE blends (Imamura et al., 2014). One of the methods is to incorporate a third component into the mutually immiscible blends that can improve the compatibility of the blends. The addition of an acrylic-acid fuctionalized PP into PP/PET blends was found to improve the compatibility of the blend system (Sani et al., 2006). The last two decades, several studies have been reported concerning blending and reactive compatibilization with engineering plastics. One common method for functionalizing polyolefins is to graft maleic anhydride, methacrylic acid or etc onto polyolefins (Al-Malaika, 1997). The compatibilizers such as maleic anhydride-graft polypropylene (MAPP) and maleic anhydride-graft polyethylene (PEMA) have been used extensively in most blends to enhance the interfacial interaction between polymer constituents and mechanical properties of the blends. The maleic anhydride grafted thermoplastic polymer can increase the polarity of the polymer molecules which introduces the polar group to the non polar PP backbone chain that results in better interfacial adhesion. The novel technique to prepare maleic anhydride grafted PP and PE was studied by Qiu et al., (2005). Dikobe et al., (2010) has investigated the addition of maleic anhydride-grafted- polypropylene (MAPP) as compatibilizer into the linear low-density polyethylene (LLDPE) and PP blends. The result shows improved properties and more thermally stable than LLDPE/PP.

In order to enhance further certain mechanical properties of the blends, particulate filler such as talc, calcium carbonate ($CaCO_3$), mica, kaolin or fibers were added to reinforce the polymers (Anjana et al., 2012). According to studies done by Ghalia et al., (2011) the addition of 20 wt% of calcium carbonate ($CaCO_3$) into PP/LLDPE blends has improved the tensile strength, flexural modulus, notched Izod impact strength and better interfacial adhesion compared to blends without $CaCO_3$. Studies done by Echevarria et al., (1998) showed there were increment in Young's modulus and flexural modulus while yield strength and elongation at break decreased with increasing filler loading for PP and talc composites. Kaolin is a mineral that has various applications in the industry, especially as filler in paper plastics, paints and rubber. Filler with hydrophilicity and the polar groups of the polymer could ease the surface bonding of the composites. This is due to the surface of the filler that easily wetted by the polymer. Therefore, to determine the reinforcing effect of polymer blends it is important to acknowledge the polarity of the polymer molecule (Anjana et al., 2012, Saleh et al., 2011). Reinforcing polymers with particulate filler would produce materials with improved performance without having expensive synthesis process (Anjana et al., 2012, Saleh et al., 2011, Ghalia et al., 2011). Al-Robaidi et al., (2013) have used kaolin as filler in the blend of isotactic PP with LLDPE and summarized that the addition of kaolin in nano size has given significant increased in the nucleation and spherulitic growth at maximum rate, thus enhanced the mechanical properties.

The main problem when preparing polymer blend with filler is the incompatibility between the phases of the blends. The addition of compatibilizers can increased the compatibility between the phases of the blend, which results in a finer morphology, better adhesion between the phases of the blends and leads to better properties of final products. Compatibilizers are often used to enhance interfacial adhesion between filler and polymers in order to obtain improvement in mechanical properties. The HDPE/PP blend filled with nano-filler has been studied and characterized by Fang et al., (2010) which incorporating several maleated polyolefins as compatibilizers. The maleic anhydride-graft polyethylene (PEMA) formed better dispersion of montmorillonite (MMT) compared to maleic anhydride-graft polypropylene (MAPP). The addition of MMT into the blend enhanced the stiffness and thermal stability of the blend.

1.2 Problem statement

Thermoplastic has been widely used by the consumer all over the globe for variety of applications. The high usage amount of these thermoplastics had led to serious environmental disposal problem. The high amount of plastic waste being generated in the landfill has led to the awareness of plastic recycling. Many researchers (Rajendran et al., 2012; Rahman et al., 2012; Evelin et al., 2000; Achilass et al., 2008) have been trying to reduce the amount of thermoplastic waste materials by looking the alternative ways of recycling these plastics either by chemical depolymerisation, gasification, thermal cracking and catalytic conversion or by mechanical recycling. Mechanical plastic recycling involves transforming the polymeric wastes into plastic pellets or into secondary plastic materials. The recycled thermoplastic also has wide variety of usage such as paint containers, body armor for cyclist, soil conversion and construction. Some previous studies have been reported about blending of different types of thermoplastic. However the blend of recycled polypropylene (rPP) and recycled high density polyethylene (rHDPE) has not yet been studied.

Additives such as fillers and compatibilizers would be incorporated and can influence the properties of the polymer blends. The blending rPP and rHDPE were immiscible blends. Therefore to improve the properties of immiscible blend, the compatibilizer was added. The addition of kaolin and MAPP for different blends rPP/rHDPE was investigated to improve the properties.

1.3 Research Objectives

The objectives of this research are: