Effect of silane coupling agent and compatibilizer on properties of short rossells fiber/polypropylene composites

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ABSTRACT

Rossells fiber reinforced polypropylene composites were prepared by melt mixing. The fiber content was 20 wt%. Octadecyltrimethoxysilane (OTMS) and maleic anhydride grafted polypropylene (MAPP) were used to improve the adhesion between PP and the fiber. The mechanical, rheological, and morphological properties of the composites were investigated. Tensile strength and impact strength of MAPP modified PP composites increased with an increase of the MAPP content. However, no remarkable effect of the MAPP content on the modulus of the composites was found. OTMS resulted in small decreases of tensile strength and Young's modulus, and increase of impact strength. Scanning electron micrographs revealed that OTMS and MAPP enhanced surface adhesion between the fiber and PP.

1. INTRODUCTION

The use of natural fibers to reinforce polymers has received much attention due to environmental concern and governmental regulations. Natural fibers offer many advantages including low density, low cost, nonabrasive nature, and biodegradability. However, the main advantage of the natural fibers is their hydrophilic nature that lowers the compatibility with hydrophobic polymeric matrix which results in decreased mechanical properties of the composites. Silane coupling agents and maleic anhydride grafted polypropylene (MAPP) are used to improve interfacial adhesion between the natural fibers and thermoplastic matrix. Franco and Vega (1997) studied the effect of vinyltri (2-methoxyethoxysilane on mechanical properties of Henequen-LDPE composites and found that the small increment in the properties is attributed to an improvement in the interfacial adhesion between the natural fibers and the polymer matrix. A significant enhancement of mechanical properties, especially notched impact strength of kenaf-PP composites after modification of the fiber with amino-ethyl amino-propyl triethoxysilane was reported by Karnani et al. (1997). MAPP is a very effective compatibilizer to improve the interfacial adhesion between polar natural fibers and non-polar polymeric matrices. Both chemical and physical interactions have been observed at the interfaces between MAPP and hydroxyl groups of natural fibers. While the PP chain of MAPP diffuses into the PP matrix to form the physical interaction (entanglement). (Doan et al., 2006) Bos et al. (2006) found that MAPP improved mechanical properties and fiber/matrix adhesion of short flax fiber-PP composites. An increase of mechanical properties of sisal-PP composites was observed when MAPP was used. (Karnani et al., 1997, Fung et al., 2002) Addition of MAPP in flax-PP composites increased mechanical properties and decreased the water uptake rate. (Arbelaiz et al., 2005)

This study examines the effect of fiber treatment with octadecyltrimethoxysilane (OTMS) and the addition of MAPP as a compatibilizer on the rheological, mechanical, and morphological properties of rossells-PP composites.

2. EXPERIMENTAL

2.1 Materials

A commercial grade of isotactic PP (700J) was supplied by Thai Polypropylene Co., Ltd. Maleic anhydride grafted PP (Fusabond® P MZ 109D, DuPont) was used as a compatibilizer. Silane coupling agent used in this study was octadecyltrimethoxysilane (OTMS, Aldrich). Rossells fibers were obtained from NEP Realty and Industry Public Co., Ltd.

2.2 Preparation of fiber and composites

Rossells fibers were washed with water, dried in oven at 60°C, and cut into an approximate length of 2 cm. After that the short fibers were boiled with a methanol and benzene mixture (1:1) to remove waxes and low M.W. species and then cleaned with 2 wt% NaOH to eliminate hemicellulose. In order to modify rossells fibers with OTMS, the unmodified fibers were immersed in 2 wt% solution of OTMS coupling agent (pH 3.5) for 3 hrs. The OTMS treated fibers were washed and dried in an oven at 60°C overnight.

The composites were prepared using an internal mixer (Hakke Rheomix Polylab). The rotor speed was 50 rpm and the mixing temperature was 170°C. The fiber content used was 20 wt%. The total mixing time was 13 min. The MAPP contents were 1, 2, 4, 6, 8, 10 phr. The test specimens were molded by an injection molding (Chuan Lih Fa, CLF 80T).

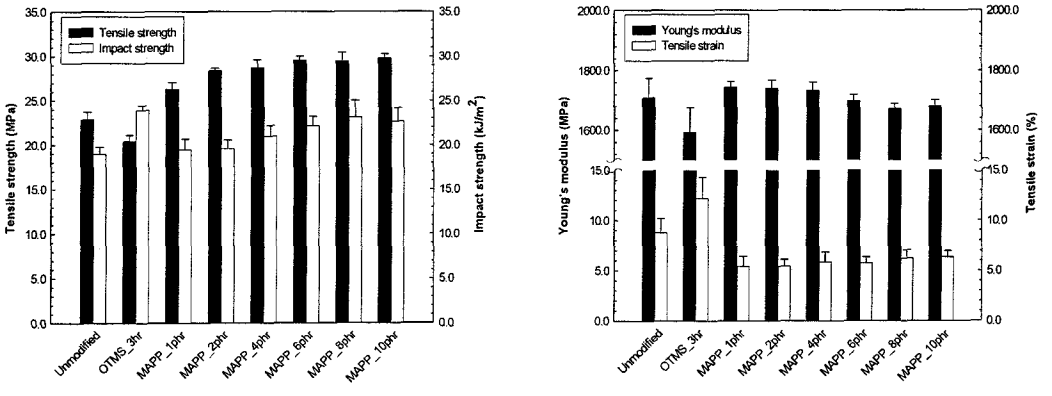
2.3 Characterization

Tensile properties of composites were tested by following ASTM D638 using an Instron universal testing machine (model 5565) with a load cell of 5kN and a crosshead speed of 10 mm/min. Impact tests were performed according to ASTM D256. Surface morphology was examined using scanning electron microscope (SEM JEOL model JSM6400) at 10keV. The samples were fractured in liquid nitrogen. Melt flow index (MFI) was measured at 180°C and 2.16 kg load.

3. RESULTS AND DISCUSSION

3.1 Mechanical properties

The tensile strength and Young's modulus of OTMS treated rossells-PP composite were lower than that of unmodified rossells-PP composite as shown in Figure 1(a) and (b). This might be come from the long and flexible octadecyl group of OTMS giving rise to flexible interfacial layer between the fiber and matrix. The tensile strain as shown in Figure 1(c) was also increased. In the case of MAPP, the tensile strength of the composites increased significantly with the addition of MAPP. Young's modulus of MAPP modified rossells-PP composites was not significant difference compared with the unmodified composite. The impact strength and tensile strain of the composites tended to increase with MAPP content. MAPP enhanced the adhesion between non polar PP and polar rossells fibers resulting in an increase in the mechanical properties. The formation of covalent linkages between maleic anhydride and hydroxyl groups of cellulose was reported by Hedenberg and Gatenholm through IR and ESCA analysis. (Hedenberg and Gatenholm, 1995)



(a) (b)

Figure 1 Effect of silane treated rossells fibers and the addition of compatibilizer on (a) tensile and impact strength, (b) Young's modulus and tensile strain of rossells-PP composites

3.2 Rheological properties

Table 1 Melt flow index of PP and rossells-PP composites

Material	Melt flow index (g/10min)
PP	4.97±0.006
Unmodified	2.57±0.014
OTMS_3hr	2.89±0.051
MAPP_1phr	2.37±0.044
MAPP_2phr	2.37±0.016
MAPP_4phr	2.19±0.034
MAPP_6phr	2.19±0.040
MAPP_8phr	2.10±0.045
MAPP_10phr	2.03±0.071

Melt flow index (MFI) of OTMS treated rossells-PP composite and MAPP modified rossells-PP composites are shown in Table 1. It can be seen that no remarkable difference in MFI of the composites.

3.3 Morphological properties

Fracture surface of the rossells-PP composites shown in Figure 2 (a)-(h) revealed that both fiber treatment and addition of the compatibilizer enhanced the surface adhesion between fiber and PP. Since the gap between fiber surface and PP matrix was reduced and the fiber surface was coated with the matrix. (Franco et. al., 1997, Bos et al., 2006) However, better surface adhesion was found in MAPP modified composites compared with OTMS treated fiber composite. This is well corresponding with the mechanical properties.

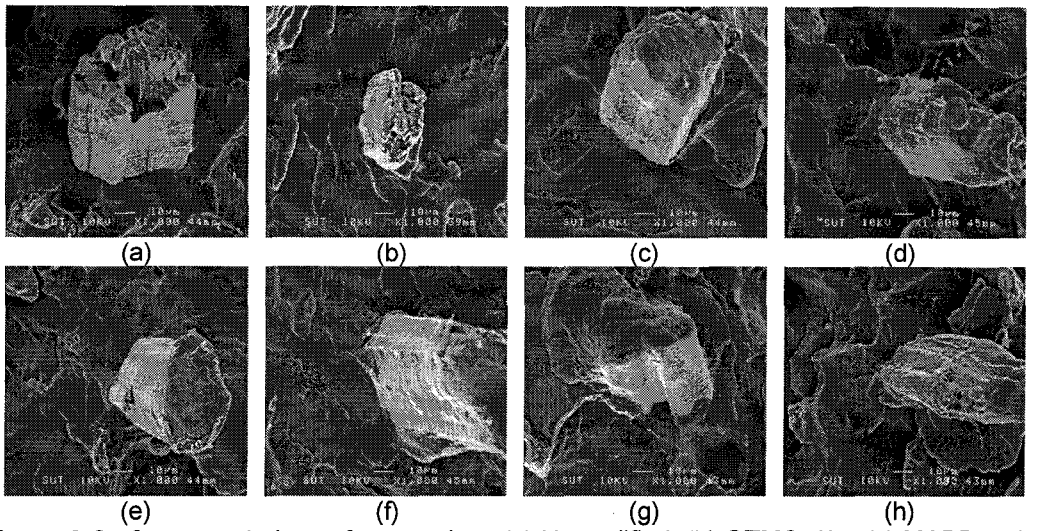


Figure 2 Surface morphology of composites; (a) Unmodified, (b) OTMS_3hr, (c) MAPP_1phr, (d) MAPP_2phr, (e) MAPP_4phr, (f) MAPP_6phr, (g) MAPP_8phr and (h) MAPP_10phr

4. CONCLUSIONS

When the rossells fibers were modified with OTMS the Young's modulus and tensile strength were not much lower than that of the unmodified composite. However, the impact strength was higher than that of the unmodified composite. The tensile and impact strength of the rossells-PP composites can be improved with the addition of MAPP due to the improvement of fiber-matrix interfacial adhesion. MAPP had no remarkable effect on modulus of the composites.

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References

Arbelaiz, A., Fernandez, B., Ramos, J. A., Retegi, A., Llano-Ponte, R., and Mondragon, I. (2005). Comp. Sci. Tech. **65**, 1582-1592.

Bos, H. L., Mussig, J., Van den Oever, M. J. A. (2006). Comp. **37**, 1591–1604.

Doan, T. T. L., Gao, S. L., and Madar, E. (2006). Comp. Sci Tech. **66**, 952-963.

Franco, P. J. H. and Vega, M. J. A. (1997). J. Appl. Polym. Sci. **65**, 197-207.

Fung, K.L., Li, R.K.Y., and Tjong, S.C. (2002). J. Appl. Polym. Sci. **85**, 169-176.

Hedenberg, P. and Gatenholm, P. (1995). J. Appl. Polym. Sci. **56**, 641-648.

Karnani, R., Krishnan, M., and Narayan, R. (1997). Polym. Eng. Sci. **37**, 476-483.