Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 9 (17): 3199-3201, 2009
ISSN 1812-5654

Mechanical Properties of α-Al_2O_3/PP Nano Composite

[1]F. Mirjalili, [1]L. Chuah, [1]A.B. Dayang, [2]M. Hasmaliza, [3]R. Aghababazadeh and [1]F. Ahmadun
[1]Department of Chemical and Environmental Engineering,
Faculty of Engineering, University Putra Malaysia, Malaysia
[2]School of Material and Mineral Resources Engineering, University Sains Malaysia, Malaysia
[3]Institute for Colorants, Paint and Coatings, Iran

Abstract: This study has focused on the effect of nano particle α-alumina on the mechanical properties of polypropylene composite was studied. The nano composites containing 1-5 wt.% of α-alumina nano particles were prepared by using a Haake internal mixer. Mixing was performed at 170°C and 30 rpm was set for the rotor speed. Some properties such as tensile strength, flexural strength, young modulus and the elongation to break were tested and were found to decrease with the addition of 2-3 wt.% α-nano alumina into the polypropylene matrix. However, with further addition of up to 3 to 5 wt.% of α-nano alumina, these parameters increased. In contrast, flexural modulus increased with an increase in the amount of α-nano alumina loading. When the weight percent was increased from 2 to 3 wt.%, the flexural strength was slightly decreased.

Key words: α-nano alumina, polypropylene, tensile strength, flexural strength

INTRODUCTION

Polymeric nano composites have been recently established as an existing new class of materials that are particle-filled, with at least one dimension of the dispersed particles being in the nanometer range. They exhibit superior mechanical performance and have improved barrier properties at very low loading levels compared to conventional filler composites (Vladimirov *et al*., 2006). The key issues in the polymer nanocomposites are: uniformed dispersion of nanoparticles against their agglomeration due to the vanderwaals bonding in the processing of nanocomposites, alignment of nanotube in the matrix, volume fraction, manufacturing rate and cost effectiveness (Huang *et al*., 2006). Researchers have tried many methods to make polymer nanocomposites such as situ intercalative polymerization and situ polymerization in the presence of nanoparticles. With regard to the cost effectiveness and feasibility of the available processing techniques, melt-blending of nanoparticles with polymer is still the optimal technique for mass production (Zhao and Li, 2005).

In this study, nano alumina is chosen as the filler because of its special combined chemical and physical properties such as excellent resistance to heat and wear, high specific strength and good oxidation resistance.

MATERIALS AND METHODS

Materials: The polypropylene used was provided by Petronas Polymer Marketing and Trading Division, Malaysia. Its density was 900 kg m^{-3}. Its melting temperature and melt flow rate were 165°C and 11 g min^{-1}, respectively. The unprocessed PP had a tensile strength of 34 MPa and a flexural modulus of 1275 MPa. Alumina nano particles used had an average particle size of 20-30 nm. The titanium dioxide powder used had a minimum assay of 98%.

Compounding and processing: The nano alumina powders were dried in an oven at 80°C for 4 h to expel the mixture before blending with PP. Mixing of alumina with PP was carried out by an internal mixer manufactured by Haake, Germany at 175°C. The rotation speed was set at 30 rpm. The first step of mixing involved the PP during preheating time for 4 min. After the preheating phase, the speed was maintained at 30 rpm for another 8 min of processing time to ensure uniformed heat distribution within the materials. Nano alumina filler was added at 8 min of processing time and titanium dioxide powder was then added 2 min later. The melt-compounded of nano alumina/PP composites were then compression molded by using HSINCHU hot press machine.

Mechanical testing: Tensile tests were carried out in accordance to ASTM D 638 using Instron Universal Testing Machine 4302. A load capacity of 1 KN at the cross head speed of 1 mm min^{-1} was used. Specimens were formed into dumbbell shape and cut from the 1 mm compression molded sheet with a Wallace die cutter. Flexural test was done under 3 point band configuration following ASTM D 790- 03 on Instron Universal Machine

Corresponding Author: F. Mirjalili, Department of Chemical and Environmental Engineering, Faculty of Engineering, University Putra Malaysia, Malaysia

5565. The samples were in rectangular shape of $(50\times12.7\times3)$ mm^3 and the cross speed of 3 mm min^{-1} was applied.

RESULTS AND DISCUSSION

The effects of nano-Al_2O_3 on tensile strength, young's modulus and percentage of elongation to break are shown in Fig. 1a-c. Having added the content of nano-Al_2O_3, the tensile strength decreased up to 2.0% and then increased. Also, the modulus values decreased at 1 wt.% of the filler loading but a positive effect up to 2 wt.% filler loading was observed. There are two reasons for the poor mechanical properties of nano-Al_2O_3 composites with pp:

- The nano particles easily caused the formation of filler agglomeration site within the matrix body which later may act as the failure initiation sites which could facilitate the propagation of the crack or fracture. Consequently, it will cause the decrease in the tensile strength value
- The surface of nano-Al_2O_3 particles is polar and pp is nonpolar so that with the addition of nano-Al_2O_3 to the pp matrix, the interface between them becomes incompatible

In the other words, the strength and the modulus of the composite cannot be greater than of the unfilled version, because the filler particles could not bear the extra fraction of the external load (Wu *et al*., 2002).

Based on Fig. 1c, the percentages of elongation at break for pp/nano Al_2O_3 composites decreased with an increase in the percentages of nano Al_2O_3 loading up to 2 wt.% and then with rising up to 3 to 5 wt.% of nano-Al_2O_3, the elongation to break slightly increased. According to Fatemeh (2006), the stiffer the material, the lower the percentages of the elongation at break will be suppressed. This was attributed to the reduction in deformability of a rigid interface between fiber and the matrix. The dramatic reduction in the elongation at break implies that the ductility of pp has been suppressed by the presence of nano Al_2O_3 (Jeefferie, 2008).

Flexural test: The results of the flexural test are shown in Fig. 2a and b. The strength values show a decrease of up to 3 wt.% followed by an increase at higher loading. From the plot, it can be observed that the nano-Al_2O_3 improves the flexural strength by developing the maximum fiber stress during the deformation in a specimen, just before it cracks or breaks. The ability to resist the deformation under the constant load given, improves

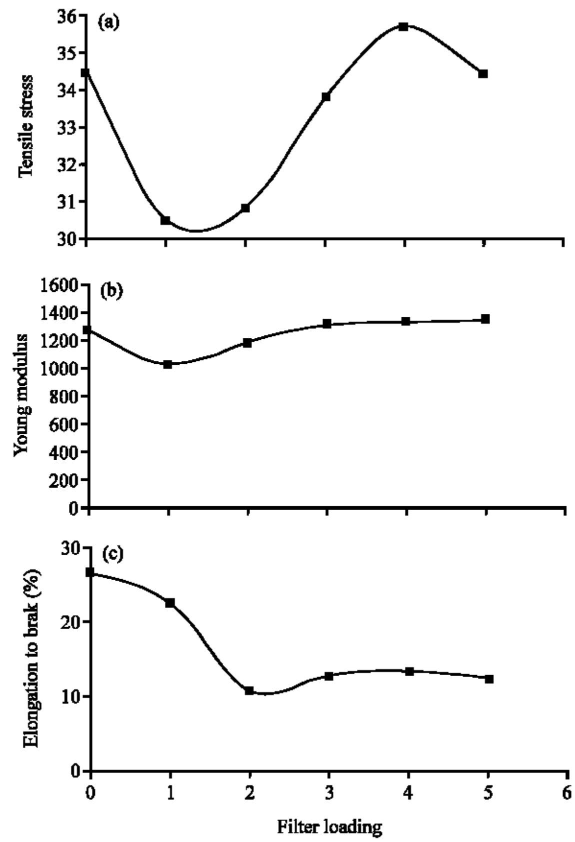

Fig. 1: Tensile properties of pp composites as a function of nano Al_2O_3 volume fraction, (a) tensile strength, (b) Young's modulus and (c) elongation to break

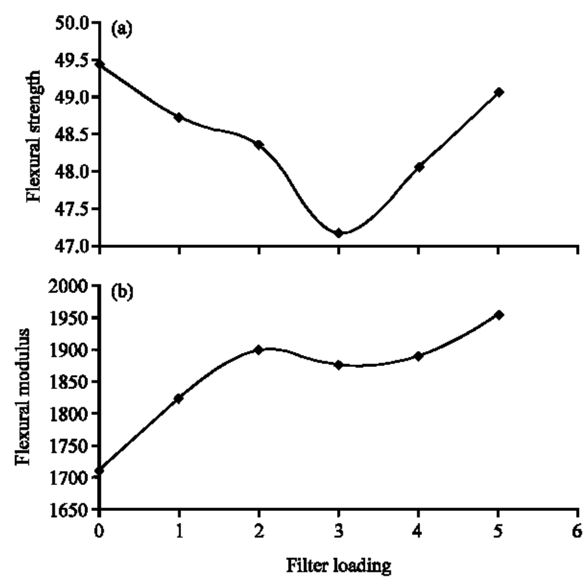

Fig. 2: Flexural properties of pp composites as a function of nano-Al_2O_3 volume fraction, (a) flexural strength and (b) flexural modulus

with the presence of nano-Al_2O_3 in the pp matrix. The improvement occurred is considered significant relative to the higher amount of the filler used. It is anticipated that the flexural strength will further increase with the addition of more than 3 wt.% of nano-Al_2O_3 loading, if and only if the interfacial adhesion between nano-Al_2O_3 and its polymer matrix is very well compatible and adhered between each other (Zhou *et al*., 2007).

Flexural modulus of nano-Al_2O_3/pp composites showed a remarkable pattern of increasing in their plot, drastically up to 2 wt.% of nano-Al_2O_3 addition after it slightly reduced at 3 wt.% of nano-Al_2O_3 loading and then improved up to 3 to 5 wt.% of nano-Al_2O_3 loading. The decreasing values of flexural strength and modulus might be due to the structure non-homogeneity structure of the mixture and/or existence of a weak bonding interface between the nano-Al_2O_3 and surrounding matrix (Lau *et al*., 2003).

CONCLUSION

The Al_2O_3 nanoparticles were dispersed in the PP matrix by internal mixing method. The results of mechanical measurements revealed that tensile, flexural, impact strengths and elongation at break reduced when 2-3 wt.% of nano Al_2O_3 loading were added. However, when the weight of α-nano Al_2O_3 increased up to 3 to 5 wt.%, these values were improved. Both Young's and flexural modulus of nano Al_2O_3/pp composite increased with the addition of α-nano Al_2O_3 compared to untreated pp.

ACKNOWLEDGMENT

The authors wish to thank the University Putra Malaysia, for supporting this study.

REFERENCES

Fatemeh, R., 2006. Development of short carbon fiber reinforced polypropylene composites for car bonnet application. M.Sc. Thesis, University of Putra Malaysia, Malaysia

Huang, L., R. Zhan and Y. Lu, 2006. Mechanical properties and crystallization behavior of polypropylene/nano-SiO_2 composites. J. Reinforced Plastics Composit., 25: 1001-1012.

Jeefferie, B.A.R., 2008. Production of carbon nanotubes filled polypropylene composites and charactization of its properties. M.Sc. Thesis. University of Putra Malaysia, Malaysia.

Lau, K.T., S.Q. Shi and H.M. Cheng, 2003. Micro-mechanical properties and morphological observation on fracture surface of carbon nanotube composite pretreated at different temperatures. Composit. Sci. Technol., 63: 1161-1164.

Vladimirov, V., C. Betchev, A. Vassiliou, G. Papageorgiou and D. Bikiaris, 2006. Dynamic mechanical and morphological studies of isotactic polypropylene/fumed silica nanocomposites with enhanced gas barrier properties. Composit. Sci. Technol.,. 66: 2935-2944.

Wu, C.L., M.Q. Zheng, M.Z. Rong and K. Friedrich, 2002. Tensile performance improvement of low nanoparticles filler-polypropylene composites. Comput. Sci. Technol., 62: 1327-1340.

Zhao, H. and R.K.Y. Li, 2005. Crystallization, mechanical and fracture behaviors of spherical alumina-filled polypropylene nanocomposites. J. Polym. Sci. Part B: Polym. Phys., 43: 3652-3664.

Zhou, H.J., M.Z. Rong, M.Q. Zhang, W.H. Ruan and K. Friedrich, 2007. Role of reactive compatibilization in preparation of nanosilica/polypropylene composites. Polym. Eng. Sci., 47: 499-509.