



Modification of nanostructure and improvement of mechanical properties of polypropylene/polyamide 6/layered silicate ternary nanocomposites through variation of processing route



P. Motamedi ^{a, b, *}, R. Bagheri ^{a, *}

^a Polymeric Materials Research Group, Department of Materials Science and Engineering, Sharif University of Technology, Tehran, P.O. Box 11155-9466, Iran

^b Chemical and Materials Engineering Department, University of Alberta, Edmonton, AB, Canada

ARTICLE INFO

Article history:

Received 10 July 2015

Received in revised form

16 September 2015

Accepted 19 September 2015

Available online 11 November 2015

Keywords:

A. Polymer–matrix composites (PMCs)

B. Mechanical properties

C. Microstructures

D. Electron microscopy

ABSTRACT

Ternary nanocomposites of polypropylene/polyamide 6/layered silicate were prepared through three different processing procedures. X-ray diffraction and transmission electron microscopy were used to study the nanostructure of the samples, and tensile and impact strength measurements were conducted to assess the mechanical properties. It was shown that processing route has a significant effect on the delamination of clay platelets. Fully exfoliated nanostructure was achieved through a certain two-step processing route. Compatibilization of the blends affected microstructure as well as nanostructure. Mechanical properties were affected by changing the processing route, to a great degree. Modification of the nanostructure, i.e. more effective dispersion of silicate layers in polyamide particles, mainly enhanced elastic modulus. Changing the microstructure, or finer dispersion of polyamide particles in the polypropylene matrix, had a major effect on yield strength. Combination of these two effects successfully created a sample with superior overall tensile properties. Impact strength, however, deteriorated with better dispersion of clay.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Blending thermoplastic polymers is a convenient and efficient way to combine the advantages of two polymeric materials with different engineering characteristics. Of particular industrial interest is adding a high-performance engineering polymer to low-price commodity thermoplastics like polypropylene (PP) and polyethylene (PE). It is well known that reinforcing commodity thermoplastics with micro-additives like CaCO₃ and talc enhances elastic modulus. But poor interfacial adhesion to the host polymer usually results in low, if any, improvement in yield strength and impact strength [1,2]. On the other hand, using engineering polymers, instead of hard inorganic fillers, can have the benefit of simultaneous improvement of several mechanical properties [3–5].

Polyamide (PA) [5], polyethylene terephthalate (PET) [6], polystyrene (PS) [7], and poly(methyl methacrylate) (PMMA) [8] are some examples of polymers used in blends based on polypropylene and polyethylene. Since polyamide, unlike polypropylene, is highly polar, due to the presence of amine groups in its chain, the two polymers are not compatible. Non-compatible polymeric blends have low interfacial adhesion and high interfacial tension, which lead to immiscibility [9,10]. Immiscible blends experience immature interphase debonding that leads to low engineering performance under relatively low stress [3,11]. One way to overcome this obstacle is reactive compatibilization, i.e. adding a copolymer capable of physical mixing with one polymer and chemical reaction with the other one. PP-g-MA [12] and EPR-g-MA [13] are two examples of reactive compatibilizers for such a blend.

Layered silicate has been long known to have a great potential for improving mechanical and physical properties of polymers, including elastic modulus, yield strength, permeability, and flame retardancy [14–17]. Successful enhancement of engineering properties of polymers through addition of nanoclay depends on effective dispersion of clay platelets inside the polymer matrix, in order to increase the polymer–filler interfacial area. This effect is maximized when total dissociation of silicate platelets occurs, and

* Corresponding authors. Polymeric Materials Research Group, Department of Materials Science and Engineering, Sharif University of Technology, Tehran, P.O. Box 11155-9466, Iran.

E-mail addresses: p.motamedi@ualberta.ca (P. Motamedi), rezabagh@sharif.edu (R. Bagheri).

an exfoliated nanostructure forms [18,19]. Realization of this complete delamination depends, to a large degree, on the existence of polar end-groups in the structure of the polymers [20].

Although nanocomposites based on reinforcement of polypropylene with layered silicate have been extensively researched, the degree of success in this field is significantly lower than that of polyamide/layered silicate nanocomposites. The authors' previous publication on this subject [21] studied the possibility of using PA6 as an intermediate phase to enhance the reinforcing potential of nanoclay in polypropylene. It was shown that the layered silicate is positioned exclusively inside PA6 particles. This leads to an intercalated structure that wouldn't be possible in the absence of polyamide, for the selected grades of polypropylene and clay. In terms of mechanical properties, it was observed that adding compatibilizer and nanoclay to the PP/PA6 blend increases yield strength and elastic modulus, respectively.

The aim of this research is to explore the possibility of achieving a fully exfoliated structure through modifying the processing procedure. Furthermore, it is desirable to understand to what extent this potential change in nanostructure affects the mechanical properties of the PP/PA6 blend, hence deciding the optimal processing route.

2. Experimental

2.1. Materials

An injection grade isotactic polypropylene from Navid-Zarshimi with the trade name of 500 M was used in this study. Polyamide 6 was a product of DSM, under the trade name of Akulon F223. Fusabond MU613U05 (polypropylene grafted with maleic anhydride) produced by DuPont was used as compatibilizer. Lastly, Nanolin DK1 organoclay, provided by FCC, was used as reinforcement. According to the manufacturer, the clay had d_{001} spacing of 2.1 nm, and cation exchange capacity of 110 meq/100 g.

2.2. Sample preparation

All the samples tested in this study were produced with 25 wt% polyamide 6, and all the reinforced samples contained 5 wt% organoclay. The compatibilized samples had 5 wt% compatibilizer. A total of eight samples were tried in this study. Four samples with codes PN, PGN, PNC, and PNGC were produced in one step melt compounding. Four other samples with codes PC + N, PGC + N, NC + P, and NC + PG were produced in a two-step processing route. The ingredients added in each step of extrusion for the samples are listed in Table 1. All the materials were dried in a vacuum oven for 24 h at 80 °C prior to the dry-blending. A Nanjing Giant twin-screw extruder ($L = 1.2$ m, $D = 53$ mm) was used for melt blending. The temperature varied from 190 to 245 °C from feeder to nozzle, while the screw rate was kept constant at 300 rpm. Extrusion was

followed by injection molding in the form of standard tensile and Charpy specimens according to ASTM D638 and ASTM D256, respectively. The temperature range used in the injection molding apparatus was identical to what used in extrusion.

2.3. Wide-angle X-ray diffraction

A Bruker AXS D8 Advance diffractometer was used for studying the nanostructure of the composites. Cu $K\alpha$ radiation was used, and machine was operated at 40 kV and 30 mA. The scan step size was 0.2° and data were collected in the range of 1.5–10°. X-ray diffraction (XRD) samples were cut from the center of the largest cross-section of the specimens, and the direction of the beam was parallel to the melt flow direction.

2.4. Transmission electron microscopy

The nanostructure of the samples was also investigated using a CM200 FEG Philips transmission electron microscope (TEM), operated at 200 kV. Blocks of the size $1 \times 1 \times 3$ mm were cut from the center of the Charpy specimens. OsO₄ staining was employed to induce contrast between polypropylene and polyamide phases. All samples were exposed to OsO₄ vapor for 120 h, before samples 60–80 nm-thick were cut from them, using a Leica UCT ultramicrotome. This step was carried out at room temperature, using a diamond blade.

2.5. Scanning electron microscopy

Scanning electron microscopy (SEM) was used for two different aims: studying the microstructure and the deformation mechanism in the samples. Deformation mechanisms were investigated by studying the fracture surface of the Charpy specimens, after fracture at room temperature. A Philips XL30 was used for this aim. However, for investigation of the microstructure, the samples were cryo-fractured in liquid nitrogen. In order to reveal the microstructure, the polyamide particles were removed using formic acid. Solvent extracting was carried out at 50 °C for 2 h. A Tescan Vega machine was used. All SEM samples were gold-coated prior to imaging.

2.6. Mechanical tests

Uniaxial tensile test was used to determine the elastic modulus and yield strength of the materials. A computerized Tinius-Olsen H10KS machine, equipped with a 100SC extensometer was used for this aim. The tests were carried out according to the standard ASTM D-638 with the cross-head speed of 5 mm/min on injection molded samples. Average of five independent test results were used for reporting each data point. The impact strength was determined through standard Charpy tests, according to ASTM D256 standard. A Santam machine with a 1J pendulum was used for Charpy tests. In this case, each data point represents the average of eight independent tests.

3. Results and discussion

3.1. Nanostructure and microstructure

It is necessary to differentiate between two terms extensively used in this study: the term nanostructure refers to the dispersion of clay platelets in the polymeric matrix, i.e. intercalated vs. exfoliated formations. The term microstructure, on the other hand, is used to describe the distribution, size, and shape of polyamide particles inside the polypropylene matrix. Nanostructure was

Table 1
The ingredients used for preparation of the first and the second step of extrusion for various samples.

Sample code	First step extrusion	Second step extrusion
PN	PP + Nylon	
PGN	PP + PP-g-MA + Nylon	
PNC	PP + Nylon + Clay	
PNGC	PP + Nylon + PP-g-MA + Clay	
PC + N	PP + Clay	First step + Nylon
PGC + N	PP + PP-g-MA + Clay	First step + Nylon
NC + P	Nylon + Clay	First step + PP
NC + PG	Nylon + Clay	First step + PP + PP-g-MA

Download English Version:

<https://daneshyari.com/en/article/817147>

Download Persian Version:

<https://daneshyari.com/article/817147>

[Daneshyari.com](https://daneshyari.com)