Journal of Alloys and Compounds 495 (2010) 596–597

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: www.elsevier.com/locate/jallcom

Mechanical properties of nylon 6/Brazilian clay nanocomposites

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ARTICLE INFO

Article history:
Received 7 July 2008
Received in revised form 16 October 2009
Accepted 23 October 2009
Available online 3 November 2009

Keywords:
Nanocomposites
Nylon 6
Organoclay

ABSTRACT

In this work, nanocomposites of nylon 6 with montmorillonite clay, untreated and treated with two different quaternary ammonium salts (Dodigen and Genamin) were obtained. The originality of this work is that the study includes the Brazilian clay, different clay treatments and the comparison of the results from mechanical properties and X-ray diffraction of nanocomposites. The results indicated that the quaternary ammonium salts were intercalated between the layers of clay, causing an expansion of the interlayer spacing. The obtained nanocomposites showed better mechanical properties when compared to nylon 6. Apparently the treated and untreated clay were compatible with the polymer matrix and presented an exfoliated nanocomposite structure. So, the nanocomposites showed an increase in tensile modulus and yield strength and a decrease in elongation.

1. Introduction

Nanotechnology is believed to harbour the potential to become a key technology, especially since two different promising major approaches can be observed in this field: first, miniaturization beyond the micrometer scale into the nanoscale; and second, the exploitation of "new" effects that arise from nanostructured materials [1,2].

A variety of inorganic materials, such as glass, fiber, talc, calcium carbonate, and clay minerals, have been successfully used as additives or reinforcement to improve the stiffness and strength of polymer. The extent of property enhancement depends on many factors including the aspect ratio of the filler, its degree of dispersion and orientation in the matrix, and the adhesion at the filler–matrix interface [3–6]. Recent interest in polymer/nanoclay nanocomposite systems is motivated by the possibility of achieving enhanced properties and added functionality at lower clay loading as compared to conventional micron size fillers [7]. For instance, adding montmorillonite clay to nylon 6 increases modulus, yield strength, heat distortion temperature [8] and also improves barrier [9]. Nylon 6/clay nanocomposites have gained much attention since Toyota researchers first demonstrated a stunning improvement of mechanical properties, as compared to pure nylon 6. However, the majority of studies have concentrated on synthesis method and the thermodynamics property of nylon 6/clay nanocomposite. No work has been done to improve solvent barrier performance of nylon 6 using layered silicate, although silicate layers have excellent barrier property to almost all molecules [10].

In this work, nylon 6 nanocomposites with Brazilian montmorillonite clay untreated and treated with two different quaternary ammonium salts (Dodigen and Genamin) were obtained and characterized by X-ray diffraction and mechanical properties.

2. Experimental

2.1. Materials

Nylon 6 was supplied by Rhodia/Brazil. It was used Na-Montmorillonite clay (MMT, Brasgel PA, Boa Vista/Paraíba, Northeast of Brazil) supplied by *Bentonit União Nordeste*. The used quaternary ammonium salts for the modification of MMT were: hexadecyltrimethylammonium chloride (Genamin) and alkyldimethylbenzylammonium chloride (Dodigen), supplied by Clariant/Brazil.

2.2. Preparation of organoclay

Organophilic montmorillonite with Dodigen and Genamin salts was prepared according to the procedure described by Araújo et al. [11–13].

2.3. Nanocomposites preparation

In the nanocomposites preparation, before any processing step, all the materials with nylon 6 were dried in oven with circulate air at 80 °C for 1 h. Following, these materials were kept in an oven under vacuum at 80 °C for 24 h. Nylon 6/organoclay nanocomposites, containing 3 wt.% of clay, were melting compounded in a counter-rotating twin-screw extruder (Torque Rheometer Haake) operating at 240 °C and 60 rpm. In order to assure a better dispersion of the fine clay powder in nylon polymer, a 1:1 nylon 6/organoclay master was previously produced in a Torque Rheometer Haake with internal mixer, at 240 °C and 60 rpm for 10 min.

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0925-8388/$ – see front matter
doi:10.1016/j.jallcom.2009.10.201

Table 1
Mechanical properties of nylon 6 and its nanocomposites.

Material	Tensile modulus (GPa)	Yield strength (MPa)	Elongation at yield (%)
Nylon 6	2.1 ± 0.10	64.97 ± 0.56	16.06 ± 0.60
Nylon 6/untreated clay	2.4 ± 0.04	68.52 ± 0.90	11.53 ± 0.40
Nylon 6/organoclay-Dodigen	2.7 ± 0.10	71.06 ± 1.14	12.66 ± 0.07
Nylon 6/organoclay-Genamin	2.5 ± 0.20	71.18 ± 0.28	11.02 ± 0.70

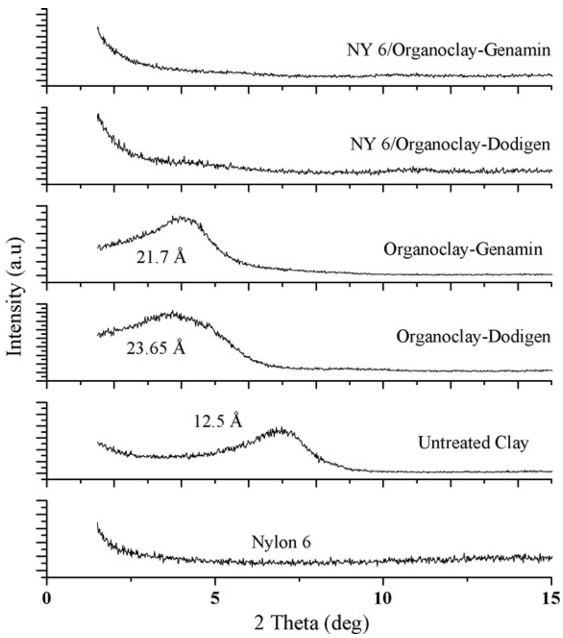

Fig. 1. XRD patterns of untreated clay, organoclay, pure nylon 6 and its nanocomposites.

3. Results

Fig. 1 presents the X-ray patterns of the untreated clay, organoclay, pure nylon 6, nylon 6/organoclay and nylon 6/clay nanocomposites. To the untreated clay, it can be seen the characteristic peak at basal distance of d_{001} = 12.5 Å. The interlayer spacing for the treated sample with two quaternary ammonium salts obtained from the corresponding XRD patterns is 21.7 Å (organoclay with Genamin) and 23.65 Å (organoclay with Dodigen), respectively. The interlayer distance was determined by the diffraction peak in the X-ray method, using the Bragg equation. The results indicated that the quaternary ammonium salts were intercalated between the basal planes of clay, leading to an expansion of the interlayer spacing. To the nanocomposites, it was observed the absence of the characteristics peak from clay and this can indicate a nanocomposite with exfoliated structure, according to Araújo et al. [11–13]. In this way, it was evident that the studied salts were efficient in the organophilization of the clay.

Table 1 shows yield strength, tensile modulus and elongation at yield of pure nylon 6 and its nanocomposites. From these results it can be seen that the nanocomposites presented a small increase in the tensile modulus and yield strength when compared with nylon 6. Apparently the nanocomposites prepared with treated clays showed superior results in relation to the untreated clay. As indicated in Table 1, the tensile modulus and yield strength of the organoclay nanocomposites produced with Dodigen and Genamin were similar and the elongation at yield for the nanocomposites with Dodigen organoclay is more or less the same as that of the Genamin organoclay and untreated clay. So, it can be concluded that the nanocomposites samples exhibited better mechanical properties in relation to pure nylon 6.

4. Conclusions

Nylon 6/Brazilian clay nanocomposites were obtained and the effect of untreated and treated clay with quaternary ammonium salts on the structure and mechanical properties of nylon 6 nanocomposites was studied in this work. These Brazilian clays are used mainly as drilling fluids, dispersant agents and present potential to be used in nanocomposite applications. The results indicated the quaternary ammonium salts were intercalated between the basal planes of clay, leading to an expansion of the interlayer spacing. Nanocomposites with organoclay and nylon 6 were obtained with success. The XRD patterns confirmed the exfoliated structure of nanocomposites. It was also observed that the nanocomposites samples exhibited better mechanical properties than pure nylon 6.

Acknowledgements

The authors would like to thank Bentonit União Nordeste for the donating the clay, to Rhodia for the donating the nylon 6, to RENAMI (Rede de Nanotecnologia Molecular e de Interfaces), to ANP/PRH-25, to MCT/CNPq, to Clariant/PE and PROCAD/NF.

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