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Effect of clay types on the processing and properties of polypropylene nanocomposites

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Abstract

The effect of clay chemistries and sources on the processing and properties of the nanocomposites made therefrom has been studied. A number of nanocomposites were prepared using different types of clay by melt processing using a Brabender plasticorder. Various analysis techniques were used to characterize the dispersion and the properties of the nanocomposites, using scanning electron microscopy (SEM), differential scanning calorimetry (DSC) and dynamical mechanical analysis (DMA).

Keywords: Polypropylene; Intercalant; Nanoclay; Intercalation; Exfoliation; Coupling agent

1. Introduction

Polymer nanocomposites is a new class of composite materials derived from nanoparticles with at least one dimension in the nanometer range. These nanoparticles are dispersed in the polymer matrix at a relatively low loading (often under 6% by weight). Because the nanoparticles (such as nanoclays, nanofibers, carbon nanotubes, etc.) are so small and their aspect ratios (largest dimension/smallest dimension) are very high, even at such low loadings certain polymer properties can be greatly improved without the detrimental impact on density, transparency, and processability associated with conventional reinforcements like talc or glass. In general, nanoparticles can significantly improve the stiffness, heat deflection temperature (HDT), dimensional stability, gas barrier properties, electrical conductivity, and flame retardancy of the polymer matrix [1,2].

Among polymer nanocomposites, those based on polypropylene (PP) and nanoclay have attracted considerable interest [3–13] because PP is one of the most widely used and fastest growing class of thermoplastics, while nanoclay is one of the most widely accepted and effective nanoreinforcements. However, scientists and engineers are faced with several challenges. Nanoclay is naturally hydrophilic whereas PP has no polar groups in its backbone and is one of the most hydrophobic polymers. The result is usually a low level of dispersion of the clay platelets in the PP matrix and a poor interfacial bonding between the clay surface and the PP matrix. This limits the advantages of incorporation of the nanoclay into the polymer matrix. Attempts to resolve these problems involve modification of the nanoclay surface and the matrix. Several types of commercial organo-clay are currently available [14,15]. In general, the main difference among them concerns the organic modifiers (intercalants), whose organic cations can replace the cations (Na^+) on the clay surface and are tailored to the polymer in which the clay would be incorporated. Some examples of these organic cations are alkyl ammonium ion, alkyl amine, etc. Therefore, the intercalants

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are widely used to improve the compatibility of nanoclay with the matrix.

The objective of the work described here is to study the effect of intercalants chemistry and concentration on processing, morphology, and properties of PP nanocomposites. The preparation method used in this work is melt compounding and compression molding, rather than twin-screw extrusion followed by injection molding as normally done. This is to obtain knowledge on the behavior of the nanocomposites when they are prepared using this technique. This paper reports preliminary results on the effect of different types of clay, which contain different intercalants, on processing and mechanical properties of PP nanocomposites.

2. Experimental

2.1. Materials

The polypropylene (PP) used in this study was PP6100SM, a general-purpose injection grade from Montell.

Six different types of commercial clay tabulated in Table 1 were used. Na denotes the non-modified montmorillonite clay. Cloisite 15A, 20A and 30B, provided by Southern Clay Products Inc., are clays modified by alkyl ammonium. Nanomer I30E and I31PS, supplied by Nanocor Inc., are clays modified by alkyl amine. Table 1 provides the technical details of nanoclays used in this study [14,15].

2.2. Nanocomposite preparation

The mixtures were prepared by mixing in a C.W. Brabender PL2000 Plasticorder. The mixing temperature was kept at 180 °C in order to ensure proper viscosity for the mixing while at the same time minimizing degradation. The rotation speed was set at 60 rpm. After all ingredients were introduced into the Brabender, melt mixing was continued for an additional period of 5 min. The total weight of material per batch was 40 g, which gives a suitable volume for the Brabender mixer. In all the nanocomposite samples, the concentration of nanoclay was kept at 3 wt.%.

Specimens for testing were prepared in a Model M Carver Laboratory Press under a pressure of 40,000 psi, with a temperature of 180 °C for both upper and lower platens.

2.3. Characterization

The characterization of the materials was done using the following instruments. Data concerning the rheological behavior during mixing was collected directly from the Brabender mixer.

A JEOL JSM-840A SEM was employed to observe the microstructures of the materials. This can be used to evaluate the dispersion of the clay inside the polymeric materials.

TA Instruments – DSC 2010 was used to obtain the crystallization and melting curves. The samples were heated to 200 °C under nitrogen atmosphere and kept at this temperature for 5 min before cooling down in order to assure that the materials melted uniformly and to eliminate the thermal history. The sample was then cooled down to room temperature at a cooling rate of 10 °C/min. From the crystallization curves that were recorded by computer, crystallization temperature (T_c) and crystallinity degree (X_c) can be obtained. Melting temperature (T_m) was detected under the same conditions at heating rate 10 °C/min.

A Du Pont 983 DMA instrument was used to characterize the mechanical behavior of the material at different temperatures. Specimens with dimensions $L/T > 10$ (where L is the length and T is the thickness) were prepared by compression molding. The dynamic properties were studied in fixed frequency mode at a frequency of 1 Hz, and the strain amplitude was 0.2 mm. The samples were heated in the temperature range from −40 to +160 °C at a heating rate of 5 °C/min.

3. Results and discussion

3.1. Rheological behavior

In general, it is difficult to compare the torque values for different composites because the torque is strongly deter-

Table 1
Characteristics of the nanoclay

Sample	Intercalant	Modifier concentration (meq/100 g)	Gallery distance (X-ray results) (Å)	Supplier
Na	–	–	–	Southern Clay Products Inc.
15A	2M2HT[a]	125	28.5	Southern Clay Products Inc.
20A	2M2HT	95	24.2	Southern Clay Products Inc.
30B	MT2EtOH[b]	90	18.5	Southern Clay Products Inc.
I30E	Octadecylamine	–	–	Nanocor Inc.
I31PS	Octadecylamine + silane	–	–	Nanocor Inc.

Note: meq/100 g is a measure of the cation exchange capacity (CEC). This is the milliequivalents of charge exchanged per 100 g mass of the clay. It represents a charge per unit mass, and in SI units, is expressed in "coulombs per unit mass". A CEC of 1 meq/g is 96.5 coulombs/g. Cation exchange capacity measurements are performed at a neutral pH of 7. The CEC of montmorillonite varies from 80 to 150 meq/100 g.

[a] 2M2HT = dimethyl di(hydrogenated tallow) quaternary ammonium.

[b] MT2EtOH = methyl, tallow, bis-2-hydroxyethyl, quaternary ammonium.