Relating Mechanical Behavior to Polyamide/Clay Nanocomposites Morphology

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INTRODUCTION

The number of papers published on nanocomposites has grown exponentially within the last decade. The montmorillonite / polyamide 6 family of reinforced polymers has been since then the most extensively studied polymer / clay nanocomposite system, and is at the center of a number of fundamental developments as well as the basis for a variety of commercial materials. Despite the efforts of the international community, however, recent reviews1,2 point out the persistent difficulty in identifying universal trends in these materials, due essentially to the inherent complexity of these systems - hence the recently expressed need3 to develop experimental tools to gain further insight into both the morphology of these systems and their macroscopic behavior.

In order to deconvolute the morphological parameters that determine mechanical properties in polymer nanocomposites, amorphous polyamides of similar polarity to polyamide-6 have been chosen as polymer matrices. This enables us to study the role played by the filler particles alone, independent of changes in crystal structure, in altering the observed macroscopic behavior of the polymer / clay nanocomposites thus formed.

MATERIALS

Three commercial resins have been selected for this work: Grilamid TR 55 and Grilamid TR 90 from EMS Grivory, and Selar PA 3426 from DuPont. Cloisite 30B from Southern Clay is used as the nanofiller, and consists of agglomerated stacks of Montmorillonite nanolayers slightly less than 1 nm thick and ~75-300 nm across, modified by bis(hydroxyethyl)methylolacteaylammonium cations.

The polymer pellets were ground into a fine powder prior to processing to ensure good mixing with the Cloisite 30B powder. All polymer-clay powder pre-mixes were dried overnight at 80°C under primary vacuum following blending, and stored in a dessicator until processed. All nanocomposites were compounded and extruded using a Leistritz ZSE-27 HP40D twin-screw extruder, after which they were dried and injection-molded.

EXPERIMENTAL

The classical nanocomposite characterization techniques of Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Differential Scanning Calorimetry (DSC) and Wide Angle X-Ray Scattering (WAXS), are carried out in order to assess the structures of these materials. This combination of analyses enables us to comment on the multi-scale morphology of the various polymer nanocomposites.

Tensile tests are carried out both at room temperature and at a high temperature. Dynamic Mechanical Analysis (DMA) experiments are performed at 1 Hz, from -150 °C to 200 °C.

DISCUSSION

We report the processing of well-dispersed clay nanocomposites based on fully amorphous, highly polar polymer matrices. The amorphous polyamides used have enough of a polar character to favor thermodynamically stable exfoliation of the montmorillonite layers via interaction with the polymer, with dispersion further enhanced by the shear fields present in the twin-screw extruder.

Though slightly affected by heat (the nanocomposite samples are yellow in color, versus the pure polymers, which are nearly colorless), the polymer nanocomposites are transparent, even in the bulk form.

Neither the chosen processing techniques nor the presence of the nanofiller affects the amorphous character of the matrix.

Based on WAXS and TEM, the fillers are shown to be fully dispersed at the nanoscale. Dispersion on the micron-scale has qualified as good through SAXS experiments.

The evolution of the polymer nanocomposites elastic properties versus the filler inorganic content are the first object of our investigation. At room temperature, the observed increase in elastic modulus can be accounted for by classical composite approaches, such as a self-coherent scheme for example4. At high temperature, the experimental increase can not be fitted by these models, however. We focus on accounting for the orientation of the filler within the sample and the anisotropy of the layer. Quantification of the orientation and proper anisotropic models should allow us to account for the observed increase in the high temperature elastic properties of our samples. More work along these lines is currently underway.

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REFERENCES