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Research paper

Effects of nanoclay addition on phase morphology and stability of polycarbonate/styrene-acrylonitrile blends

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ABSTRACT

In this work, an extensive study was performed on the compatibility and morphological stability of polycarbonate/styrene-acrylonitrile (PC/SAN) blends and on the effects of nanoclay addition to these systems. PC/SAN blends of different compositions were prepared by melt extrusion and their morphologies were characterized as prepared and after annealing at high temperature to evaluate their morphological stability. The effects of nanoclay with different organic modifiers and acrylonitrile (AN) content in the SAN copolymer on the morphology of the PC/SAN blends were also evaluated. The results indicate that the nanoclay reduces the domain size of SAN phase and stabilizes the system morphology even without complete exfoliation. Organoclays particles with polar organic modifiers were preferably located inside the SAN domains, while in blends containing organoclays with nonpolar modifiers, the clay particles migrated to the interface, resulting in domain reduction and improved morphological stability.

1. Introduction

Blending two or more polymers is an effective approach to obtain systems with properties better than the individual polymers. However, most polymer blends are thermodynamically immiscible. Polycarbonate/styrene-acrylonitrile (PC/SAN) is a typical example of an immiscible blend, which was poor mechanical properties due to high interfacial tension despite the existence of a certain degree of interaction between the components. Chaudhry et al., 1998, have demonstrated the tendency of the PC/acrylonitrile-butadiene-acrylonitrile styrene (ABS) system to phase separate. PC/ABS system is similar to PC/SAN and shows low morphological stability, restricting the practical application of this material. To achieve high-performance polymer blends, it is essential to control and stabilize the blend morphology. Compatibility of components in polymer blends is generally achieved by incorporating graft or block copolymers, which reduce the domain sizes and enhance the interfacial adhesion between the phases (Macosko et al., 1996). However, the production of these compatibilizers is usually difficult and expensive.

Several recent studies have reported the compatibilizing effect of organoclay additives in immiscible polymer blends (Vo and Giannelis, 2007; Filippone et al., 2010; Moghbelli et al., 2010; Tiwari and Paul, 2011; Nazari et al., 2012; Chen et al., 2013; Labaume et al., 2013a, 2013b). The use of organoclay additives has many advantages over the traditional approach of adding block copolymers, such as the ready availability of clays, lower cost, and easy processability. The effect of clay platelets on the morphology of polymer blends is yet to be completely explored. When the organoclay is located in the continuous phase, the domain size of the dispersed phase is reduced because the organoclay increases the viscosity in the matrix and acts as a physical barrier, reducing the coalescence rate of the dispersed phase. To maximize this effect, it is necessary to have the clay platelets located at the interface of the system (Si et al., 2006; Hemmati et al., 2014). On the other hand, when the clay is located within the dispersed phase, it appears to increase the dispersed phase domain size (Gahleitner et al., 2006; Sinha Ray et al., 2004; Zhang et al., 2012). Thus, the present study was designed to evaluate the effects of organoclay (OC) addition on compatibility, morphology and morphological stability of PC/SAN blends. The PC/SAN system is particularly interesting because the viscosity and polarity of the system can be modified by using SAN copolymers with different AN content (Callaghan et al., 1993; Hanafy et al., 2004), which might lead to a change in the localization of the organoclays.

2. Experimental

2.1. Materials

A PC resin (Lexan® 101) with a melt flow index of 7 g/10 min (300 °C/1.2 kg), purchased from SABIC, was used as the matrix. Two SAN resins (supplied by BASF), Luran 358 N and Luran 388 S with

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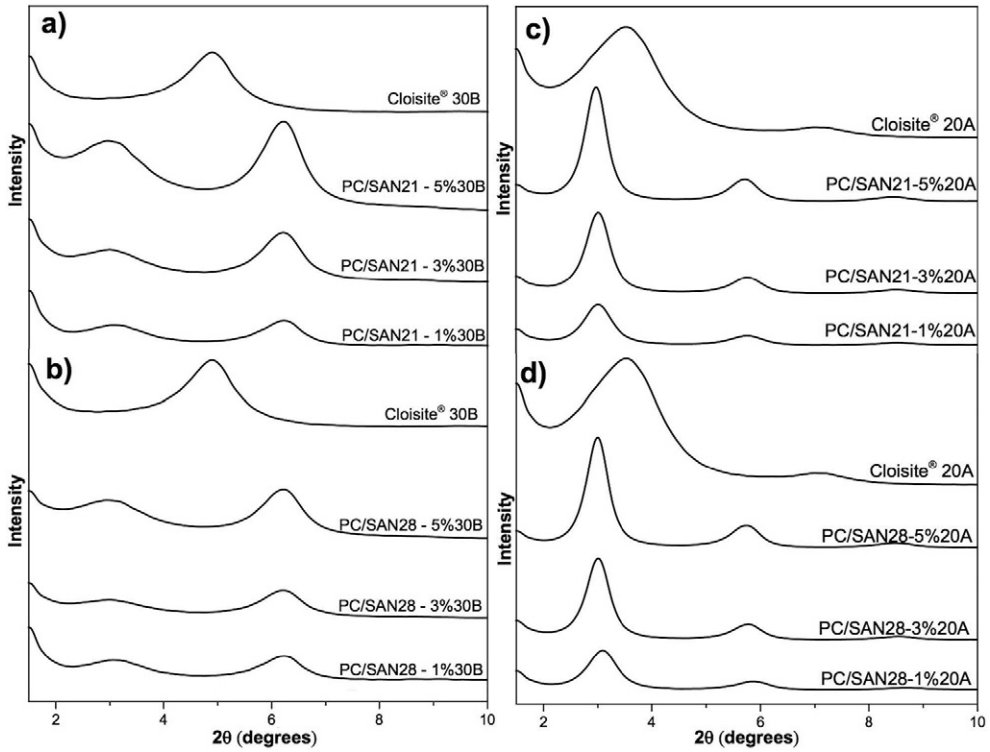

Fig. 1. WAXD patterns of the neat organoclays Cloisite® 30B and Cloisite® 20A and the ternary (PC/SAN/organoclay) systems.

melt flow indices of 6.3 g/10 min (230 °C/3.8 kg) and 2.6 g/10 min (230 °C/3.8 kg), respectively, and AN content of 21 wt% and 28 wt%, respectively, were used. These SAN resins will hereafter be denoted (based on the AN content) as SAN21 and SAN28, respectively. Organoclays Cloisite® 20A and Cloisite® 30B were purchased from Southern Clay Products Inc. Cloisite® 30B is a natural montmorillonite with, was a cation exchange capacity near 90 meq/100 g, which was treated with methyl tallow bis-2-hydroxyethyl quaternary ammonium chloride to form a polar organoclay. Cloisite® 20A is also a natural montmorillonite, which was treated with a low-polarity dimethyl dehydrogenated tallow quaternary ammonium chloride to form a non-polar organoclay. The difference in the polarity of the clays can be expected to alter the position of the organoclay platelets in PC/SAN mixture. The location of the clay platelets might also be altered with an increase in the AN content because SAN is expected to interact more with Cloisite ®30B than with Cloisite ®20A due SAN polarity.

2.2. Blend preparation

All the materials were vacuum dried at 90 °C for 24 h prior to melt processing. The PC/SAN/organoclay blends were prepared in a twin-screw extruder (B & P Process Equipment Systems, model MP19, with L/D ratio = 25 mm and length = 19 mm). The temperature profile used was 185, 195, 195, 200, and 205 °C and the screw speed was set at 140 rpm. The extrudates were pelletized and then vacuum dried again for 8 h at 80 °C. The PC/SAN/organoclay pellets were molded in an injection-molding machine (Arburg 270 V) with an injection pressure of 94 MPa and a holding pressure of 60 MPa. The temperature profile used was 200, 220, 230, 230, 240 °C and the mold temperature was set at 65 °C. The specimens were prepared using an injection mold that produces samples following ASTM D256-06 standards used in Izod impact tests. The composition of the PC/SAN blend was fixed at 70/30 wt% ratio and the organoclay content was 1, 3, or 5 wt%. For comparison, PC/SAN21 and PC/SAN28 blends without the clays were also prepared under the conditions described above.

2.3. Annealing

The specimens were annealed at 170 °C for 60 min to evaluate the morphological stability of the PC/SAN/organoclay blends. The treatment conditions are less aggressive than that normally reported in the literature (Vo and Giannelis, 2007; Triantou and Tarantili, 2014). The altered annealing conditions were necessary to avoid organoclay degradation and to prevent bubble formation in samples, which could negatively affect transmission electron microscopy (TEM) observations.

2.4. Wide angle X-ray diffraction (WAXD)

X-ray analysis was carried out in reflective mode (in a Rigaku Multiflex diffractometer) with Cu-Kα rays (wavelength = 1.542 Å). The scan rate was 1°/min and the 2θ range was 1–10°.

2.5. Morphology characterization

The SAN dispersed domains and the location of the OC in the blends were evaluated by TEM. The Izod specimens were sliced to reveal the

Table 1
d-Value obtained from the XRD patterns.

Neat Cloisite® 30B	d001 (Å) 18.0
PC/SAN21–1% 30B	28.5
PC/SAN21–3% 30B	29.5
PC/SAN21–5% 30B	30.5
PC/SAN28–1% 30B	28.5
PC/SAN28–3% 30B	30.5
PC/SAN28–5% 30B	29.5
Neat Cloisite® 20A	24.9
PC/SAN21–1% 20A	29.4
PC/SAN21–3% 20A	29.4
PC/SAN21–5% 20A	29.8
PC/SAN28–1% 20A	28.7
PC/SAN28–3% 20A	29.4
PC/SAN28–5% 20A	29.4