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Effects of polybutadiene-g-SAN impact modifiers on the morphology and mechanical behaviors of ABS blends

X.F. Xu [a], R. Wang, Z.Y. Tan [a], H.D. Yang [b], M.Y. Zhang [b], H.X. Zhang [a,b,*]

[a] *Changchun Institute of Applied Chemistry, Graduate School, Chinese Academy of Sciences, Changchun 130022, PR China*
[b] *Institute of Chemical Engineering, Changchun University of Technology, Changchun 130012, PR China*

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Abstract

A series of PB-g-SAN impact modifiers with different ratio of PB to SAN ranging from 20.6/79.4 to 91.9/8.1 were synthesized by seeded emulsion polymerization. ABS blends were prepared by blending these PB-g-SAN impact modifiers and SAN resin. The rubber concentration of these ABS blends was kept at a constant value of 15 wt%. The influences of different impact modifier on the mechanical behavior and morphology of ABS blends have been investigated. The dynamic mechanical analysis on ABS blends shows that T_g of the rubbery phase shifts to a lower temperature, $(\tan\delta)_{max}$ of the rubbery phase increases and then decreases with the increase of PB concentration in PB-g-SAN impact modifier. A uniform dispersion of rubber particles in the matrix can be observed when PB/SAN ratio in PB-g-SAN impact modifier is in the range from 20.6/79.4 to 71.7/28.3. When it exceeds 71.7/28.3, an agglomeration of rubber particles occurs. The mechanical tests indicate that the ABS blend, in which PB/SAN ratio in the impact modifier is 71.7/28.3, has the maximum impact strength and yield strength.

Keywords: ABS; Blends; Grafting degree; Morphology

1. Introduction

ABS (acrylonitrile–butadiene–styrene) resin is a rubber-toughened thermoplastic, the dispersed rubbery phase is polybutadiene (PB) and the continuous rigid phase is acrylonitrile–styrene copolymer (SAN). Polybutadiene particles are grafted with SAN to achieve the necessary interaction with the SAN matrix. ABS resin is typically produced by the so called "emulsion grafting and blending method", it includes the following process: the production of PB latex by emulsion polymerization, the emulsion grafting of acrylonitrile/styrene onto the PB latex to produce ABS impact modifier, the production of SAN resin, and the melt blending of the ABS impact modifier and the SAN resin to get the ABS resin product.

The properties of ABS are influenced by the morphology and structure of rubber phase. Many authors have observed that some of the most important factors in controlling the structures of rubber phases and consequently controlling the mechanical properties of ABS are rubber particle size [1,2] and the volume fraction of the rubbery phase [3,4]. The understanding of the

* Corresponding author. Tel.: +86 431 582 6774; fax: +86 431 591 5530.
E-mail addresses: xuxinfeng@mail.ccut.edu.cn (X.F. Xu), zhhx@ciac.jl.cn (H.X. Zhang).

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relationships between structure and properties of rubber modified glassy polymers is a complex problem because of the numbers of structure variables involved, and this is evident from the summary of the manufacturing routes and polymer blend properties described by Bucknall [1]. Kim et al. [5] have studied the effect of acrylonitrile content on the toughness of ABS materials, the main variables in their study included the AN content of the SAN graft (14.2–37.5%) and the AN content of the SAN matrix (14.7–40%), they found that mechanical properties of ABS blend are best when the AN content in the matrix is higher than that of the graft. The span of AN differential that results in blends of superior properties becomes wider as the graft AN content is increased. While the AN content of the SAN grafted butadiene rubber was fixed at 22.5%, maximum strength and toughness were observed for compositions based SAN matrices containing 34% AN. They suggested that when using grafted rubber particles of similar size and morphology, there are at least three major factors that influence the mechanical properties of SAN/SAN-grafted-rubber blends. They are interfacial adhesion, state of rubber particle dispersion and the inherent ductility of matrix SAN. The inherent ductility of the matrix polymer provides a rational basis for understanding the properties of toughened SAN copolymers by SAN emulsion grafted rubbers.

When the same SAN matrix is used, the properties of ABS blends are dependent on the characteristics of PB-g-SAN impact modifier. Thus the design of PB-g-SAN impact modifier is of great importance not only to the industrial production but also to the theoretical research of ABS. This paper aims at studying the relation between the structure of the PB-g-SAN impact modifier and the mechanical behavior of the ABS blends produced from these impact modifiers in order to obtain the optimum design of the PB-g-SAN impact modifier. In this paper, a series of PB-g-SAN impact modifiers with PB/SAN ratio ranging from 20.9/79.4 to 91.9/8.1 were synthesized and ABS blends were prepared by blending these impact modifiers with SAN resin. In all the ABS blends the PB content was kept at the same level of 15 wt%, which provided an equal condition for the comparison of mechanical properties between different samples in order to find a correlation between morphology of rubber particles and the mechanical properties of the ABS blends.

2. Experimental

2.1. Materials

Polybutadiene (PB) latex with 325 nm of the average latex particle size was supplied by Jilin Chemical Company, China. PB-g-SAN impact modifiers were synthesized by grafting styrene and acrylonitrile monomers onto polybutadiene (PB) latex rubber particles, the characteristics are listed in Table 1.

SAN resin which contains 25 wt% AN was supplied by Jilin Chemical Company, China. M_w and M_n for SAN resin are 148,000 and 49,400 g/mol, respectively.

2.2. Measurement of latex particle diameter

Particle size and particle size distribution of the PB and PB-g-SAN latex were measured by a Brookhaven 90 Plus Laser Particle analyzer.

2.3. Determination of grafting degree and grafting efficiency of PB-g-SAN impact modifiers

The PB-g-SAN impact modifier was dissolved in acetone, the un-grafted SAN is soluble in acetone, and the PB-g-SAN copolymer is insoluble. Grafting degree and grafting efficiency were determined by means of ultracentrifugation. They were calculated as follows [2]:

$$\text{Grafting degree}(\%) = 100 \times (\text{gel}\% - \text{PB}\%)/\text{PB}\%$$

$$\text{Grafting efficiency}(\%) = 100 \times (\text{gel}\% - \text{PB}\%)/(1 - \text{PB}\%)$$

where gel% is the weight fraction of the acetone insoluble part in the sample and PB% is the weight fraction of polybutadiene in the PB-g-SAN sample.

2.4. ABS blends preparation

ABS blends were obtained by melt blending PB-g-SAN impact modifiers and SAN resin using a twin-screw extruder at 220 °C. In all the ABS blends, the PB content was kept at the same level of 15 wt%. The composition of ABS blends is listed in Table 2.

2.5. Dynamic mechanical thermal analysis

Dynamic mechanical thermal analysis for ABS blends was performed on a METRAVIB MAK-04 VISCOANALYSER at a frequency of 10 Hz and a heating rate of 3 °C/min with the temperature range from −120 to −20 °C, the dimensions of the specimens were 20 mm × 12 mm × 2 mm.

2.6. Examination of mechanical properties of ABS blends

The dimensions of all the specimens obtained by injection molding for notched Izod impact strength test were 63.5 mm × 12.7 mm × 6 mm. The test was conducted on AJU-22 Impact tester at room temperature.

All materials for tensile test were injection molded into dumb-bell type specimens whose dimensions of the parallel part were 60 mm in length with a cross-section