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Compatibilization of acrylonitrile-butadiene-styrene terpolymer/poly(ethylene glycol-*co*-1,4-cyclohexanedimethanol terephthalate) blend: effect on morphology, interface, mechanical properties and hydrophilicity

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ABSTRACT

The compatibilization of acrylonitrile-butadiene-styrene terpolymer (ABS) and poly(ethylene glycol-*co*-1,4-cyclohexanedimethanol terephthalate) (PETG) blends was first investigated. Styrene-acrylonitrile-glycidyl methacrylate terpolymer (SAG) and ABS grafted with maleic anhydride (ABS-g-MAH) were selected as reactive compatibilizers for the ABS/PETG blends. The compatibilization effect was assessed by scanning electron microscope (SEM), differential scanning calorimetry (DSC) and mechanical properties. And the effect of compatibilizers on the hydrophilicity of the blends was evaluated as well. SEM observation and DSC analysis confirmed that both SAG and ABS-g-MAH compatibilizers could improve the compatibility between ABS and PETG, leading to an improvement in toughness of the blend. The possible cause for the improvement of compatibility was the reaction between compatibilizers and PETG, which could *in situ* turn out compatibilizers that acted as interfacial agents to enhance the interfacial interaction in the blend. Especially, the addition of SAG significantly decreased the dispersion phase size and the interface voids almost disappeared. Since the *in situ* reactions between the epoxy groups of SAG and the end groups (—COOH or —OH) of PETG generated PETG-co-SAG copolymer at the blend interface, and the cross-linking reactions proposed to take place between SAG and the PETG-co-SAG copolymer, acting as compatibilizer, could significantly increase the interfacial interaction. The addition of SAG also enhanced the stiffness of the blends. Moreover, the addition of SAG made the blend more hydrophilic, whereas the addition of ABS-g-MAH made the blend more hydrophobic. Therefore, SAG was a good compatibilizer for the ABS/PETG blends and could simultaneously provide the blends with toughening, stiffening and hydrophilic effects.

1. Introduction

Acrylonitrile-butadiene-styrene terpolymer (ABS) consists of a butadiene rubber embedded in a matrix of styrene-acrylonitrile copolymer, and is generally noted for its excellent toughness and dimensional stability [1,2]. Due to its excellent properties, ABS is widely applied in the manufacturing of components and parts such as golf club heads, bumper bars and protective headgear [3]. However, the hydrophobic property of ABS owing to its rich hydrophobic groups [4,5] will severely limit the use of this polymer in some fields, in which hydrophilicity is required. The surface hydrophilic modification of ABS can be realized in many methods to meet the demands of concrete applications. And incorporating hydrophilic polymer into ABS is an effective way to afford ABS hydrophilicity.

In our previous work [6], poly(ethylene glycol-*co*-1,4-cyclohexanedimethanol terephthalate) (PETG) random copolymer was used as modifier to modify the surface hydrophilic property of ABS by melt-blending. PETG is synthesized *via* copolymerization with purified terephthalic acid, ethylene glycol and 1,4-cyclohexanedimethanol [7]. Incorporating PETG into ABS could improve the hydrophilic property of the ABS/PETG blends. And the hydrophilic property of the blends was enhanced with increasing PETG content. However, increasing content of PETG led

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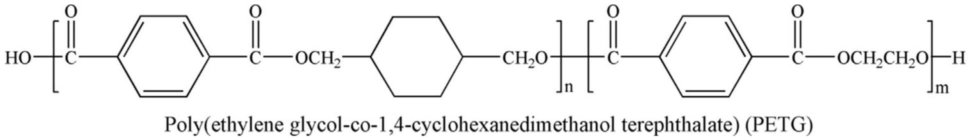

Scheme 1. Chemical structure of the PETG copolymer.

to an obvious decrease in impact strength of the blends due to its poor compatibility between ABS and PETG. In addition, the compatibilization of the ABS/PETG blends has not been reported so far. Therefore, a well justified study regarding the compatibilization of the ABS/PETG blends appears to be necessary.

Reactive compatibilization of immiscible polymer blends has attracted a very considerable attention in recent years [8]. Essentially, the chemical reactions between the blending polymers with reactive functional groups are able to generate *in situ* formation of compatibilizers at the interface during melt-blending. These compatibilizers can reduce interfacial tension and enhance interface adhesion between the blending polymers [9].

In this paper, we selected styrene-acrylonitrile-glycidyl methacrylate terpolymer (SAG) and ABS grafted with maleic anhydride (ABS-g-MAH) as reactive compatibilizers to improve the compatibility between ABS and PETG. The compatibilization effect of SAG and ABS-g-MAH to the ABS/PETG blends was evaluated by scanning electron microscope (SEM), differential scanning calorimetry (DSC) and mechanical properties. Meanwhile, the effect of the compatibilizers on the hydrophilicity of the ABS/PETG blends was investigated as well.

2. Experimental

2.1. Materials

The polymers used in this study were obtained from commercial sources. ABS (D-120, density = 1.03 g/cm^3) was purchased from Zhenjiang Chi Mei Chemicals Co., Ltd., China. PETG (S2008, density = 1.27 g/cm^3) was purchased from SK Chemicals Co., Ltd., Korea and its chemical structure is shown in Scheme 1 [10]. SAG and ABS-g-MAH were selected as reactive compatibilizers for the ABS/PETG blends. SAG were purchased from Fine-blend Compatilizer Jiangsu Co., Ltd., China. ABS-g-MAH were supplied by Nanjing Tough Plastic Co., Ltd., China. ABS, PETG and ABS-g-MAH were supplied as pellets, whereas SAG was supplied as powder.

2.2. Samples preparation

Blends of ABS/PETG were prepared in 70/30 and 30/70 blend ratios (W/W), respectively. Concentrations of compatibilizers (SAG and ABS-g-MAH) were ranged from 0 to 10 phr (parts by weight per hundred parts of ABS and PETG resins). The specific formulas of the ABS/PETG blends containing different types of compatibilizers were listed in Table 1. ABS and PETG were dried in an oven at 80 °C for 4 h before use. The ABS/PETG blends were prepared *via* melt processing with a TE-35 co-rotating twin-screw extruder (Coperion Keya (Nanjing) Machinery Co., Ltd., China), which was equipped with a screw of 36 mm in diameter and L/D ratio of 32. The barrel temperature, from the entrance to the exit, was 195, 245, 245, 225, 225, 210 and 195 °C, respectively. The blended and dried pellets were molded into standard test specimens by using a CJ80M3V injection molding machine (Chen De Plastics Machinery Co., Ltd., China) at 245 °C.

2.3. Characterizations

2.3.1. Mechanical properties

The notched Izod impact tests of the ABS/PETG blends were carried out on a UJ-4 impact tester (Chengde Machine Factory, China), according to the ISO 180. The tensile and flexural tests were measured using a CMT 5254 universal testing machine (Shenzhen SANS Testing Machine Co., Ltd., China). The tensile tests were performed at a stable rate of 5 mm/min according to the ISO 527 and the flexural tests were performed at a stable rate of 2 mm/min according to the ISO 178. Before being tested, all the specimens were annealed in an oven at 90 °C for 4 h. For all of the above mechanical tests, 5 specimens were measured and averaged.

2.3.2. SEM observations

The fracture surface morphology of Izod impact tested specimens was observed by SEM in a JSM-5900 microscope (JEOL, Japan) at 15 kV accelerating voltage after gold coating.

2.3.3. Differential scanning calorimetry measurements

The glass transition temperatures (T_gs) of the ABS/PETG blends were detected by a Q2000 differential scanning calorimeter (TA Instruments, America). The DSC measurement was performed using about 10 mg sample sealed into an aluminum pan under nitrogen atmosphere with a purge flow of 50 mL/min. The sample was heated from room temperature to 200 °C at 40 °C/min and kept isothermally for 1 min to erase the previous thermal history. Then,

Table 1
Formulas of the ABS/PETG blends containing different types of compatibilizers (phr).

Sample codes		Composition			
		ABS	PETG	SAG	ABS-g-MAH
ABS/PETG = 70/30	Control	70	30	0	0
	SAG5	70	30	5	0
	SAG10	70	30	10	0
	MAH5	70	30	0	5
	MAH10	70	30	0	10
ABS/PETG = 30/70	Control	30	70	0	0
	SAG5	30	70	5	0
	SAG10	30	70	10	0
	MAH5	30	70	0	5
	MAH10	30	70	0	10

phr: Parts by weight per hundred parts of ABS and PETG resins.