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Effect of the compatibilizers on polycarbonate (PC) /acrylonitrile-butadiene-styrene (ABS) blend

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Abstract
Blends of polycarbonate (PC) and acrylonitrile-butadiene-styrene (ABS) were prepared and some mechanical, morphological properties and thermal stability were investigated. We selected the ratio of 80/20 to prepare PC/ABS alloys. Two kinds of compatibilizers, methacrylate-butadiene-styrene (MBS) and styrene-maleic anhydride (SMA) were used to improve the compatibility between PC and ABS. The results showed that SMA had no significant effect on the tensile strength of the blends while MBS decreased the tensile strength of blends a lot. Results of notched charpy impact strength tests showed that SMA increased the impact strength of blends more than MBS. The maximum increase was about 36.4 % when using 15wt% of SMA. Scanning electron microscopy micrographs showed that the particle size of ABS was decreased in the continuous phase of PC by using the compatibilizers. Moreover, differential scanning calorimetry (DSC) curves proved both MBS and SMA could make the glass transition temperature (Tg) of two phase close to each other. Finally, thermogravimetric tests showed that MBS and SMA had little effect on thermal stability of the PC/ABS blend.

1. Introduction

Polycarbonate (PC)/ poly (acrylonitrile-butadiene-styrene) (ABS) blend is one of the most wildly-used engineering plastics in industry. In recent years large amounts of this blend is used in the automotive industry, domestic appliances, electrical and electronic equipment [1]. Although PC /ABS blend is known for special applications, it usually needs compatibilizer to enhance the adhesion strength between PC and ABS resin. This is because the wettability and surface energy are poor and low between PC and ABS resin [2].

As PC and ABS are not completely miscible [3], many researchers use a variety of compatibilizers to improve the compatibility. Ordinarily, three types are considered to reduce the interfacial tension between PC and ABS resin, including block or graft copolymers, nonreactive polymers containing polar groups and reactive functional polymers [4]. Many researchers have studied the effect of using various compatibilizers such as styrene-butadiene-styrene(SBS) block copolymer and ABS-g-(maleic anhydride) (ABS-g-MA) on mechanical properties. Ouyang et al. investigated the effect of three different kinds of new compatibilizer on the mechanical properties of PC/ABS blend. They showed that the modification effects of the three new compatibilizers were better

than the traditional compatibilizer such as PE-g-MA. A small amount of new compatibilizers had a considerable effect on the notched impact strength of the blend and little effect on tensile strength [5].

For the present paper we compared two different compatibilizers, methyl methacrylate-butadiene-styrene (MBS) and styrene-maleic anhydride (SMA), to analyse the modification effect on PC /ABS blend. MBS was selected because of its rubbery nature, and then it also can play the role of impact modifier for the blends to enhance their mechanical properties, especially impact strength. SMA is a kind of rigid compatibilizer, it can increase the notched impact strength of the blend significantly and maintain mechanical properties at the same time [6].

2. Experimental

2.1. Materials

PC (L1250Y) was from TEIJIN polycarbonate LTD (Janpan) and ABS (PA-758) was from CHIMEI (Taiwan) with melt flow index (MFI) (200 ◦C, 5kg) of 3.0 g (10 min)$^{-1}$. Styrene-maleic anhydride (SMA) was supplied by Sinopec Shanghai Petrochemical Company Limited (China). Methacrylate-butadiene-styrene (MBS) was purchased from ROHM and HAAS Company (USA).

2.2. Blend Preparation

A commercially available weight ratio 80:20 of PC and ABS was used in the experiment.

PC and ABS were dried for 4 h respectively at 120℃ and 80℃. Then, the mixes were melt-blended according to the formulations given in Table 1 using a co-rotating twin-screw extruder (ZSK-25WLE) with L/D ratio of 40. The screw speed was 120rpm and the temperatures of the extruder zones were adjusted from 200℃ to 240℃. After extruding, the resulting pellets were dried at 80℃ for 8h and then injection moulded (JPH-10) into various shapes corresponded to the characterizations discussed below. The injection temperature profile was adjusted from 220℃ to 250℃. Finally, the samples were annealed in the drying closet for 4h at 80℃.

Table 1. *Formulation of blends*

	Components(phr)											
	A_0	A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4	B_5	B_6	B_7
PC	80	80	80	80	80	80	80	80	80	80	80	80
ABS	20	20	20	20	20	20	20	20	20	20	20	20
MBS	0	2	4	6	8	0	0	0	0	0	0	0
SMA	0	0	0	0	0	2	4	6	8	10	15	20

2.3. Characterization

2.3.1. Mechanical Testing

Tensile strength and percentage tensile elongation at break (ultimate elongation) were determined at 25 ℃ using a universal testing machine (LR30K, Ametek Co., England) according to Chinese standard GB/T1040-2008. And the tensile speed was 50 mm • min^{-1}. Notched Charpy impact strength was carried out at 25 ℃ using a resil impactor (Ceast Co, Italy) according to Chinese standard GB/T1843-2008. Eight specimens of each composition were tested and the average values were recorded.

2.3.2. Differential Scanning Calorimeter (DSC)

The glass transition temperature (Tg) was determined using the differential scanning calorimeter (DSC) performed on a DSC STARe (mettle-toledo Switzerland). The following parameters were applied: the temperature program between 25 ℃ and 200 ℃, two times heating and one time cooling, both at a rate of 20 ℃ • min^{-1}, and a nitrogen flow of 50 ml • min^{-1}. The sample mass was 5 mg.

2.3.3. Scanning Electron Microscopy (SEM)

The morphology of fractured surfaces of specimens from impact tests was examined using SEM (JSM-6701F). To observe the phase morphology at fractured surfaces and the phase deformation state after fracture, broken samples were etched using an acid aqueous solution. It was made of 5 g of CrO_3 dissolved in 120 ml of H_2SO_4 and 30 ml of H_2O. This solution was used to etch the ABS domains leaving unaltered the PC ones. In this case the treatment was made at 85°C for 24 minutes. After that a final prolonged washing with hot water of the surfaces for about 20 minutes was needed in order to get rid of the residual materials [7]. Finally, the impact fracture surfaces were coated with a thin gold layer before SEM examination.

2.3.4. Thermo Gravimetric Analyzer (TGA)

Thermogravimetric analysis (TGA) was performed on TGA Q500 (TA) apparatus to investigate the thermal decomposition of the PC/ABS blend under N_2 atmosphere. Samples of 5 mg were heated from 40℃ up to 700 ℃ with heating rate of 10℃/min.

3. Results and Discussion

Blends with various concentrations of compatibilizer from 0 to 20 wt% (Table 1) were prepared to investigate the effect of using two different compatibilizers on mechanical properties such as tensile and impact. The results and comparison diagram are showed in Figure 1 and Figure 2.

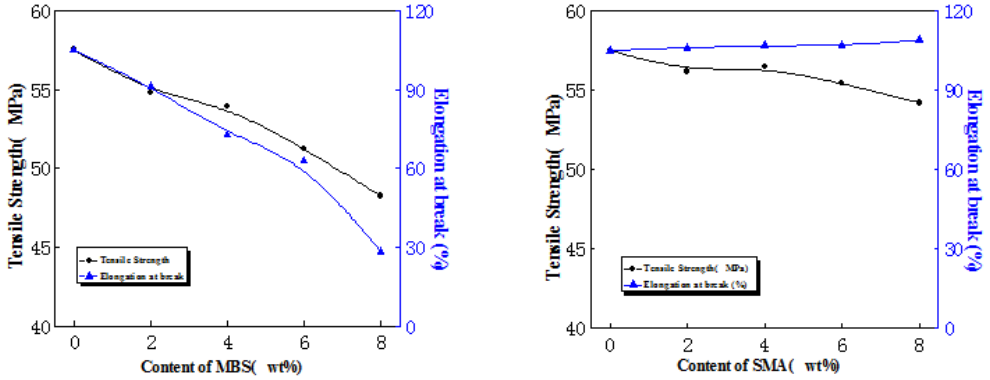

Figure 1. *Effect of SMA and MBS on the tensile strength of PC/ABS blend*

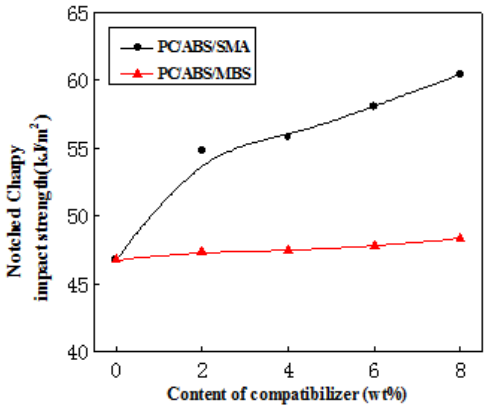

Figure 2. *Effect of SMA and MBS on impact strength of PC/ABS blend*

Table 2. *Mechanical prosperity of PC/ABS/SMA*

Sample	Tensile Strength/MPa	Elongation at break/%	Impact strength/KJ/m^2
A_0	57.52	105.13	46.79
B_1	56.20	106.23	54.80
B_2	56.49	106.99	55.82
B_3	55.45	107.00	58.06
B_4	54.23	109.08	60.43
B_5	51.57	111.02	61.90
B_6	48.95	112.61	63.80
B_7	47.11	113.01	56.80

In Figure 1, the increasing content of compatibilizer (MBS or SMA) leads to a drop in tensile strength of blends. This is because the elastic modulus of MBS or SMA itself is lower than that of PC and ABS. However, the tensile strength of blends modified with SMA decreases less than that with MBS when increasing the amount of compatibilizer. The elongation at break of PC/ABS/MBS blend decreases to 24.68%, when PC/ABS/SMA blend increases to 106.8%.

Figure 2 and Table 2 show that the impact strength of the blends initially increases with increasing amount of compatibilizer (MBS or SMA) up to 8 wt%. Moreover, the increase of impact strength of blends when using SMA is more than that when using the same amount of MBS as compatibilizer. This could be due to the chemical reaction between MA groups of the SMA and hydroxyl and groups in PC [8-10]. The interface strength between PC and ABS was increased [11]. Besides that, SMA having the same portion of PS with ABS is another reason.

For PC/ABS/SMA blend, the maximum impact strength occurs， when using 15wt% SMA for compatibilizer, with values of 63.80 kJ·m^{-2} which increased about 36.4%.

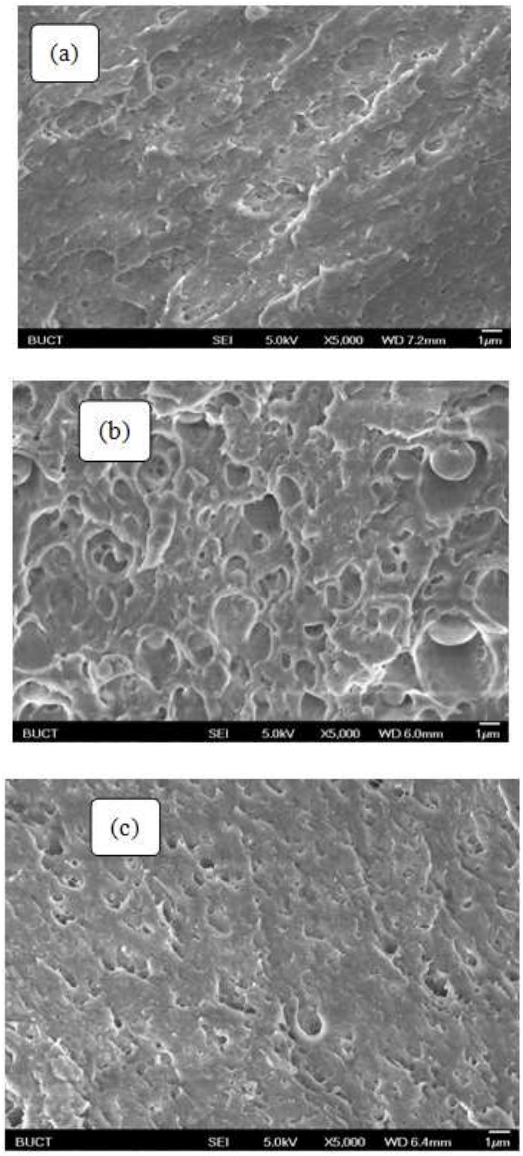

Figure 3. *SEM photomicrographs (×5000) of PC/ABS blend: (a) without compatibilizer; (b) with MBS; (c) with SMA.*

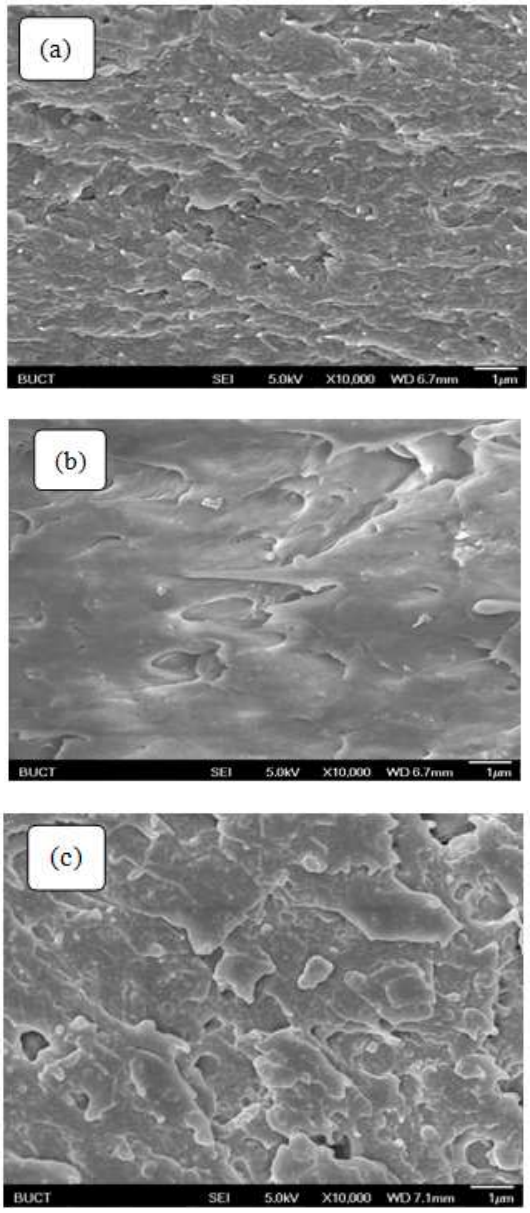

Figure 4. *SEM photomicrographs (×10000) of PC/ABS blend: (a) without compatibilizer; (b) with MBS; (c) with SMA.*

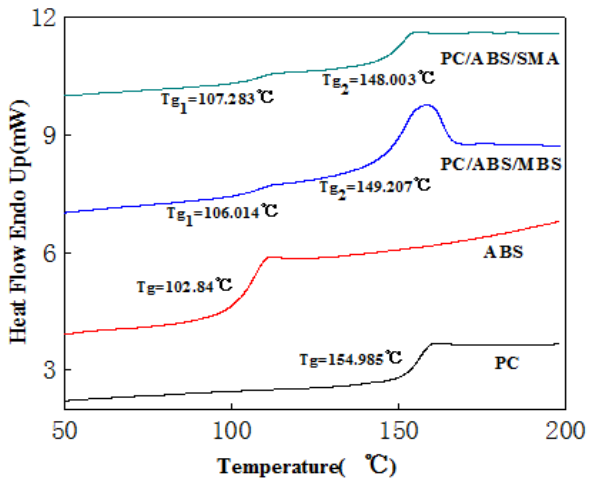

Figure 5. *DSC curves of PC/ABS blends*

Table 3. *Glass transition temperature (Tg) of blends*

Sample	Tg_1/℃	Tg_2/℃
Pure PC	154.985	-
Pure ABS	-	102.840
PC/ABS/MBS	149.207	106.014
PC/ABS/SMA	148.003	107.283

In this research, PC is continuous phase, and ABS is dispersed phase. The SEM photomicrographs from Figure 3 show that, the dispersed domains of ABS in the noncompatibilized blend are greater and more heterogeneous than in the compatibilized ones. In addition, combination with 3(c) photomicrograph and mechanical properties, SMA is better than MBS on compatibilizing effect of PC/ABS blend. This could be because of the reaction that occurs between MA groups of the SMA and hydroxyl end groups of PC that improved the interfacial interactions between the blend components [12]. Figure 4 shows the impact fracture surfaces of blends with and without compatibilizers. According to Figure 4, blends with and without compatibilizers both show ductile fracture behavior. The fracture surface of blend without any compatibilizer exhibits a relatively smooth surface in comparison to blends with MBS and SMA. This phenomenon is in agreement with the impact strength data and result of Figure 3.

For a better analysis, DSC curves were shown to judge the compatibility of PC/ABS blend in Figure 5 and Table 3. According to the DSC curves of blends without and with compatibilizers a change of the glass transition temperature (Tg) can be seen. The glass transition temperature of pure PC and ABS is respectively 154.985℃ and 102.840℃. However, two kinds of compatibilized blends both show two Tg. This is because the PC and SAN phase in the ABS have a good compatibility, and the PC and the PB phase in the ABS is incompatible [13, 14]. Compared with the pure component before blending, Tg of PC phase in alloys removes to low temperature region, while Tg of SAN phase transfers to high temperature region. The Tg of two phase become close to each other, indicating that the two compatibilizers both have compatibilizing effect on the PC/ABS alloy.

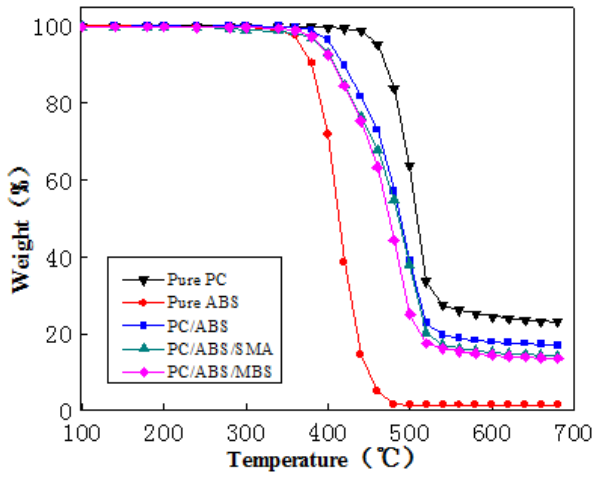

Figure 6. *TGA curves of PC/ABS blends heated in nitrogen*

The thermal gravimetric graphs (Figure 6) show that blends with and without compatibilizers nearly has the same decomposition temperature. So, the addition of SMA or MBS has little effect on thermal stability of the PC/ABS blend.

4. Conclusions

As PC and ABS are not completely miscible, compatibilizers are needed during blending. Blends of PC and ABS were prepared with two different compatibilizers. The results show that MBS has no significant effect on the impact strength of the blends. The tensile strength and the elongation at break of the blends decreases gradually with increasing amount of MBS as compatibilizer.

Addition of SMA up to 20wt% increased the impact strength significantly for the PC/ABS alloy. The maximum impact strength occurs with values of 63.80 kJ•m−2, which increased by 36.4%. There are no considerable differences between tensile strength results of unmodified and modified blends when using SMA.

Also, SEM photomicrographs of sample with SMA show better dispersion of ABS as dispersed phase in compatibilized blends compared to the non-compatibilized one. Moreover, the blend without compatibilizer showed brittle behaviour while the blends containing compatibilizer showed ductile behaviour in fracture. DSC curves indicate that SMA is a better compatibilizer in PC/ABS blend than MBS. Finally, thermogravimetric tests show that MBS and SMA have little effect on thermal stability of the PC/ABS blend.

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