The compatibilizer content effect on tensile and flexural properties of PC/ABS blends

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Abstract. In this research, the effect of styrene-maleic anhydride (SMA), methyl methacrylate-butadiene-styrene (MBS) and maleic anhydride–grafted ABS (ABS-g-MAH) compatibilizer on thermal and mechanical properties of polycarbonate (PC) and poly(acrylonitrile–butadiene–styrene) (ABS) blends were studied. PC/ABS blends samples with varying contents of compatibilizer were prepared. With the compatibilizer content increases, the results indicated that the effects of these three compatibilizers on PC/ABS blends are not exactly the same. When the SMA content increases from 5 to 20 wt%, the impact strength reduced by about 76% from 43.24 kJ/m² to 10.20 kJ/m². The SEM picture indicated that when SMA content exceeds 5 wt%, SMA resin begins to aggregate and leading to inadequate interfacial bonding between SMA and PC/ABS phases. The results showed that about 5 wt% of ABS-g-MAH can improve the impact strength of the blends by about 113% and have little effect on the tensile and flexural properties. Similarly, when the MBS content reaches about 5 wt%, the impact strength of PC/ABS blends is increased by about 112%, but as the MBS content increases to 20 wt%, the tensile and flexural properties reduced by about 25%.

1. Introduction
PC/ABS blends combine the advantages of PC and ABS. PC resin contributes to mechanical strength and thermal stability, ABS resin contributes to process [1]. However, the poor compatibility between PC and ABS results in poor mechanical strength of their blends [2-4]. Therefore, many researchers have begun to research the use of compatibilizers to improve PC/ABS compatibility [3-8]. Farzadfar et al. [7] carried out a study on the PC/ABS blends containing various content of EVA-g-MAH, and the influence of this compatibilizer on mechanical strength, tensile strength decrease and impact strength increases with increasing EVA-g-MAH content. Balakrishnan et al [8] investigated the strength of PC/ABS blends with ABS-g-MAH at different levels, and PC/MABS blends showed great improvement in impact strength than PC/ABS. However, there are few studies on the effects of different compatibilizers and their contents on the performance of PC/ABS blends. In this paper, the effects of three compatibilizers, SMA, MBS and ABS-g-MAH and their contents on the mechanical properties, thermal properties and morphology of PC/ABS blends were studied.
2. Experimental

2.1. Materials
The PC (Makrolon 2807) used in this study was from Bayer Material Science Company (Germany) (density = 1.2 g/cm³, MFI (melt flow index) = 10 g/10 min (300°C, 1.2 kg)). ABS (PA-758) was obtained from ChiMei Corporation (Taiwan). This general purpose grade ABS (density = 1.08 g/cm³, MFI = 3.0 g/10 min (200°C, 5 kg)). SMA resin (1000), MBS (MB838A) and ABS-g-MAH (2360 k) were purchased from Basf SE (Germany), Dow Chemical Company (USA) and Kumho Petro Chemical (South Korea), respectively.

2.2. Blend preparation
PC and ABS were dried in an air circulating oven at 120°C and 80°C for 6 h, respectively. Three kinds of compatibilizers (SMA, MBS and ABS-g-MAH) were dried in an air circulating oven for 4 h at 80°C. Then, PC/ABS were mixed physically with the weight ratio of 50:50 in a high speed mixing machine (SHR-10A, Zhangjiagang Wankai Machinery Co., Ltd., Suzhou, China) with varying contents of compatibilizer. These three kinds of compatibilizers were added at different content of 0, 1, 3, 5, 10, 15 and 20 (wt%). The blends have been obtained by melt compounding in a co-rotating twin screw extruder (KTE-20-6, Kerke Extrusion Equipment Co., Ltd., Nanjing, China). The extruded pellets were dried at 90°C for 6h and then injection moulded (MH-35T, Dongguan Min-hui Plastic Machinery Co., Ltd., Dongguan, China) for mechanical tests.

2.3. Thermal properties
The glass transition temperature (Tg) of PC/ABS blends was tested by PerkinElmer instruments DSC 6000. The samples were scanned from room temperature to 180°C under nitrogen atmosphere at a rate of 5°C /min.

2.4. Mechanical properties
The mechanical strength tests by a universal testing machine (ETM104C, Shenzhen Wance Test Instruments Co., Ltd., Shenzhen, China) according to ASTM D-638 and ASTM D-790. Crosshead speeds of 5mm/min and 3mm/min were used for tensile and flexural testing, respectively. For each blend, the data reported is the average of five specimens. Impact tests were done according to ASTM D 256A by a plastic impact testing machine (PIT501J, Shenzhen Wance Test Instruments Co., Ltd., Shenzhen, China). For each blend, the data reported is the average of ten specimens. These tests were measured at (25±1°C) and (50±5%) relative humidity. The testing temperature and humidity were controlled by air conditioner and humidity controller.

2.5. Morphological observations
After gold coating for 2 minutes in an ion sputtering apparatus, the morphology of impact fracture section was tested by INSPECT S50 scanning electron microscopy (SEM) with 5K magnification, 20 kV and working distance was 30 mm.

3. Results and discussion

3.1. Thermal properties
The glass transition temperature (Tg) of PC, ABS, and their blends was tested by DSC. In this paper, the inflection point temperature was identified as Tg value. Figure 1 shows the DSC thermograms of pure PC and ABS. The Tg values of PC and ABS were 144.2°C and 102.2°C.
Figure 1. DSC thermograms of PC and ABS.

The DSC results obtained on samples of PC/ABS blends with 0, 1, 3, 5, 10, 15 and 20 wt% compatibilizer are summarized in Table 1. For each blend, the Tg value reported is the average of three specimens. The results show that the addition of compatibilizer reduced the difference of Tgs between PC and ABS. The decrease in the Tgs difference between PC and ABS (Tg,PC – Tg,ABS) shows improved compatibility in PC/ABS blend [9]. This shows that all these three type compatibilizers can improve the compatibility between PC and ABS.

Table 1. Tgs (°C) of PC/ABS with compatibilizer blends, as obtained by DSC.

| Compatibilizer content, wt% | SMA | MBS | ABS-g-MAH |
|---------------------------|-----|-----|-----------|
|                           | Tg,ABS | Tg,PC | ΔTg | Tg,ABS | Tg,PC | ΔTg | Tg,ABS | Tg,PC | ΔTg |
| 0                         | 102.9 | 143.8 | 40.9 | 102.2 | 138.9 | 36.7 | 102.9 | 141.1 | 38.2 |
| 1                         | 104.2 | 143.3 | 39.1 | 102.1 | 138.4 | 36.3 | 103.0 | 140.8 | 37.8 |
| 3                         | 104.3 | 142.9 | 38.6 | 101.7 | 137.9 | 36.2 | 103.1 | 140.1 | 37.0 |
| 5                         | 104.5 | 142.3 | 37.8 | 101.5 | 137.2 | 35.7 | 103.0 | 138.8 | 35.8 |
| 10                        | 104.8 | 142.0 | 37.2 | 101.3 | 136.7 | 35.4 | 102.9 | 138.5 | 35.6 |
| 15                        | 105.1 | 141.4 | 36.3 | 100.9 | 135.9 | 35.0 | 103.2 | 138.3 | 35.1 |

3.2. Mechanical Properties

The effect of compatibilizer content on the mechanical properties of PC/ABS blends is shown in Figure 2. When SMA content increases from 0 to 20 wt%, tensile strength and flexural strength decreased by about 38 and 31%, respectively, and tensile modulus and flexural modulus decreased by about 19 and 17%, respectively. The effect of compatibilizer MBS on mechanical strength and modulus of PC/ABS blends was better than that of compatibilizer SMA slightly, and compatibilizer ABS-g-MAH is much better than SMA or MBS. With the content of ABS-g-MAH increases from 0 to 20 wt%, tensile strength and flexural strength decreased by about 7 and 8%, respectively, the variation of tensile and flexural moduli was less than 3%.
Figure 2. The mechanical properties of PC/ABS blends with compatibilizer.

Figure 2(e) shows the relationship between the impact strength of the samples and the compatibilizer content. The impact strength increased at first, and then, decreased when the content of compatibilizer was over 5 wt%. With the content of SMA increases from 0 to 5wt%, impact strength increased by about 190%, from 14.93 kJ/m² to 43.24 kJ/m². When the SMA content increases from 5 to 20wt%, the impact strength reduced by about 76% from 43.24 kJ/m² to 10.20 kJ/m². This decline is owing to the inadequate interfacial bonding between SMA and PC/ABS phases [10]. Unlike SMA, the impact strength increased
with increasing content of compatibilizer MBS and ABS-g-MAH, up to 5wt%, after which they also decreased. Despite these decreases, the impact strength values for the PC/ABS blends with MBS or ABS-g-MAH were still significantly higher than for the neat PC/ABS blend. The results indicate that higher compatibilizer content will not further improve the properties of the blends and may result in the loss of this improvement [4].

3.3. Morphological observations
The SEM micrographs of fracture surface of PC/ABS blend without compatibilizer presented in figure 3. The compatibility between PC and ABS is not good, and the low impact strength of the blend without compatibilizer also indicates this issue.

Figure 3. SEM micrographs of PC/ABS without compatibilizer.
Figure 4. SEM micrographs of PC/ABS blends with: (a) 1wt% SMA; (b) 5wt% SMA; (c) 20wt% SMA; (d) 1wt% MBS; (e) 5wt% MBS; (f) 20wt% MBS; (g) 1wt% ABS-g-MAH; (h) 5wt% ABS-g-MAH; (i) 20wt% ABS-g-MAH.

Figures 4(a), 4(b) and 4(c) shows that the compatibility between PC and ABS is improved with the increasing of compatibilizer SMA. With SMA content exceeds 5wt%, SMA resin begins to aggregate, a large number of holes can be seen between SMA phase and PC/ABS, which destroys the structural integrity of PC/ABS blends and causes the PC/ABS impact strength to drop rapidly. Unlike SMA, the other picture in figure 4 shows that MBS and ABS-g-MAH do not significantly aggregate in PC/ABS blends, which improves PC/ABS compatibility.

4. Conclusions
In this study, the effect of SMA, MBS and ABS-g-MAH compatibilizers on the properties of PC/ABS blends was studied. The DSC test results show that all these three compatibilizers can improve the compatibility between PC and ABS. The effects of these three compatibilizers on the properties of PC/ABS blends were compared.

- Tensile and flexural tests show that tensile strength, flexural strength, tensile modulus, and flexural modulus decrease most with the SMA content in PC/ABS blends. When the SMA content reaches 5wt%, the impact strength of the PC/ABS blends increases by about 190%, from 14.93 kJ/m² to 43.24 kJ/m². When the SMA content increases from 5 to 20wt%, the impact strength reduced by about 32%.
- The effect of the compatibilizer MBS on the mechanical properties of PC/ABS blends is similar to that of SMA. The impact strength of PC/ABS blends increases maximally when the MBS content is 5wt%, from 14.93 kJ/m² to 31.66 kJ/m².
- As the content of ABS-g-MAH increases from 0 to 20wt%, the tensile and flexural strength values decreased by about 7 and 8%, respectively, while the variation of tensile and flexural moduli was less than 3%.
- The SEM results confirmed that when the content of SMA exceeded 5wt%, SMA resin began to aggregate in PC/ABS blends, destroying their structural integrity and sharply deteriorating their impact strength.

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