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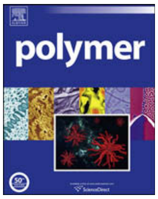

The effect of interfacial adhesion on the impact strength of immiscible PP/PETG blends compatibilized with triblock copolymers

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ABSTRACT

In this work, recycled Poly(ethylene glycol-co-cyclohexane-1,4-dimethanol terephthalate) plastic (PETG) was used to enhance the properties and lower the cost of polypropylene(PP). In order to adjust the interfacial adhesion, three triblock copolymers having the same styrene block at two ends but different block in the middle, were used a the compatibilizers, namely, styrene–ethylene/butylene–styrene (SEBS), styrene–butadiene–styrene (SBS), styrene–isoprene–styrene (SIS). The ratio of PP to PETG was fixed at 70/30 and the relationship between interfacial adhesion and mechanical properties was investigated. The addition of SIS caused a considerable increase in Izod impact toughness, but only slightly improved toughness was observed for blends compatibilized with SEBS. The effect of SBS on improving the impact toughness lied in between that of SIS and SEBS. SEM micrographs showed that PETG forms a fibrillar-like structure for all the uncompatibilized and compatibilized blends, and the blends compatibilized with SBS have smallest domain size, the blends compatibilized with SEBS have largest domain size, while the ones compatibilized with SIS show a moderate domain size. Results from melt rheometry and SEM observation together with work of interfacial adhesion, indicated a strongest interfacial adhesion in blends compatibilized with SBS, poorest in blends compatibilized with SEBS, and moderate in blends compatibilized with SIS. It is very interesting to found that the much improved impact strength was not observed in the blends with the strongest interfacial adhesion but achieved in the blend with moderate interfacial adhesion. Investigation on the impact fractured surface revealed an easier debonding of fibril from matrix and consequently drawn out of matrix in blends compatibilized by SIS with moderate interfacial adhesion, which was considered as the main reason for the much improved impact toughness in this system.

1. Introduction

Polypropylene (PP), which is one of the most important thermoplastics, is widely used in many fields. However its brittleness limits its application greatly. PP alloys with high impact strength are greatly desired. Poly(ethylene glycol-co-cyclohexane-1,4-dimethanol terephthalate) plastic (PETG), is an amorphous thermoplastic copolyester. The mechanical properties of PETG are approximate to PET. PETG is non-crystallizable, the viscous flow temperature of PETG is no more than 130 °C. And this feature makes PETG easier to processing and molding than poly(ethylene terephthalate) (PET). The combination of PP and PETG can offer some advantages over pure PP material. PETG may enhance the stiffness, flow properties of PP. Furthermore, the lower permeability of PETG towards water vapor and gases could be used in packaging materials. If the recycled PETG plastic is used, one expects additional economic and society benefits.

In previous studies, various compatibilizers were introduced to improve the compatibility of PP/PET blends. Xanthos et al. [1] reported that PP grafted with maleic anhydride (MAH) or acrylic acid (AA) could improve the compatibility of PP/PET blends. Finely dispersed phases were found by adding those compabilizers. Heino et al. [2] found that poly[styrene-b-(ethylene-co-bytylene)-b-styrene] (SEBS) grafted with MAH (SEBS-g-MAH) or glycidyl methacrylate (GMA) could act as a compatibilizer to yield a finer dispersion of dispersed phase and improve the interfacial adhesion for PP/PET blends. Pang et al. [3] studied the effects of three maleic anhydride-grafted-polypropylene derivatives as compatibilizing agent on the morphology, interface and mechanical behavior of PP/PET blends. The impact strength of the compatibilized blends was about 1.5–2 times higher than that of uncompatibilized ones. The compatibilization effects were determined by means of modulated-temperature differential scanning calorimetry (M-TDSC). In the work of Mariano Pracella et al. [4], glycidyl methacrylate modified

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SEBS and styrene-b-(ethylene-co-propylene) (SEP) were used to compatibilize PET/PP blends. The compatibilizers showed remarkable effect on the reduction of phase domain size and about two times enhancement in impact toughness was observed.

Like the PP/PET blend, PP and PETG are also completely immiscible and a proper compatibilizer is necessary, otherwise, blends with coarse morphology and poor properties will be resulted. In this article, recycled PETG was used to blend with PP, and three familiar and commercially available triblock copolymers were employed as the compatibilizers, namely, styrene–ethylene/butylene–styrene (SEBS), styrene–butadiene–styrene (SBS), styrene–isoprene–styrene (SIS). All of them have the same styrene block at two ends but different blocks in the middle. The ratio of PP to PETG was fixed at 70/30 and the relationship between interfacial adhesion and mechanical properties was investigated. Very interestingly, much improved impact strength was not obtained in the blends compatibilized by SBS with the strongest interfacial adhesion but achieved in the blend compatibilized by SIS with moderate interfacial adhesion.

2. Experimental procedure

2.1. Sample preparation

The materials used for the preparation of PP/PETG/compatibilizers blends are listed in Table 1. Three block copolymers, namely, styrene–ethylene/butylene–styrene (SEBS), styrene–butadiene–styrene (SBS), and styrene–isoprene–styrene (SIS) were used as compatibilizers, and their molecular characteristics are shown in Fig. 1. PETG was recycled from waste film through several procedures such as breaking up, washing, heating at T_g of PETG to form particles and drying. It has an intrinsic viscosity of 0.58 g/dl according to the supplier. The fresh PETG usually has an intrinsic viscosity of about 0.7 g/dl. The ratio of PP to PETG was fixed at 70/30 and different amount of compatibilizers were used. The PETG and PP were dried at 65 °C for 4 h before used, to minimize the hydrolysis during processing. The melt blending of PP and PETG was conducted in a TSSJ-25 two-screw extruder with a barrel temperature of 200 °C, and then injection molded in PS40E5ASE injection machine between 160 and 200 °C to obtain standard specimens for mechanical tests.

2.2. Mechanical tests

The notched Izod impact strength was used to evaluate the toughness of samples. The notched specimens were tested with a VJ-40 impact test machine at room temperature, according to ISO180-1992 standard. Each impact test was repeated at least five times, and the results were averaged reported with statistical error bar. For the tensile property tests, dumb-bell shaped specimens were examined on an AG-10TA tensile testing machine at room temperature. Test speed was kept at 50 mm/min, according to ISO 5893-2002 standard. Again at least five specimens were used, and the results were averaged and reported with statistical error bar.

2.3. Melt rheometry

The rheological measurements were performed on a controlled stress rheometer (Malvern Instruments Ltd., UK) using 2.5 cm diameter parallel plates. Testing sample disks with a thickness of 1.5 mm and a diameter of 2.5 mm were prepared by compression molding of the samples at 200 °C for 3 min. The rheological properties of samples were carried out by small-amplitude oscillatory shear frequency dependence (strain = 5%) measurements within a frequency range of 0.005–1 rad/s. All these measurements were conducted under a nitrogen atmosphere to minimize oxidative degradation of the samples.

Table 1
Materials.

Materials	Brand	Supplier	Characteristic
PP	T30s	Du Shan Zi Petroleum Chemical, China	$M_w = 39.9 \times 10^4$ g/mol $M_w/M_n = 4.6$ MFI = 2.64 g/10 min (230 °C, 2.16 kg)
PETG	0725	Shengxin co. Si-chuan, China	MFI = 41.76 g/10 min (220 °C, 10 kg) $M_n = 2 \times 10^4$ g/mol
SEBS	YH-503	Yueyang Petrochemical Co. China	$M_n = 20 \times 10^4$ g/mol $M_w/M_n = 1.04$ styrene 33% mass
SBS	1401	Yueyang Petrochemical Co. China	$M_n = 10 \times 10^4$g/mol $M_w/M_n = 1.02$ styrene 30% mass
SIS	1105	Yueyang Petrochemical Co. China	$M_n = 13 \times 10^4$ g/mol $M_w/M_n = 1.02–1.03$ styrene 15% mass

2.4. Scanning electron microscopy (SEM) experiments

The samples were cryogenically fractured or impacted in the direction perpendicular or parallel to flow direction in liquid nitrogen. The fractured samples were observed in a FEI Inspect F SEM instrument, using an acceleration voltage of 20 kV. The phase morphology was directly examined without any etching. All the pictures were taken from the core layer of the samples. Images in Fig. 4 were enlarged at 6000 times, other images were all enlarged at 3000 times.

2.5. Contact angle measurements

Contact angles were measured in a sessile drop mold with KRUSS DSA100. PP, PETG, SBS, SEBS, SIS samples for contact angle measurement were compression molded between clean silicon wafers at 200 °C for 5 min and then cooled to 25 °C under pressure for 3 min. Contact angles were measured on 3 ml of wetting solvent at 20 °C, and the results reported were the mean values of 10 replicates.

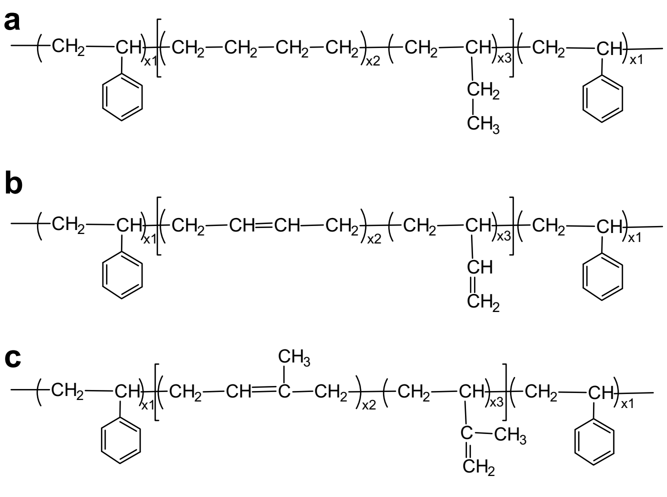

Fig. 1. The molecular structure of (a) SEBS; (b) SBS; (c) SIS triblock copolymer, ×1, ×2 and ×3 represent the polymerization degrees of the blocks of copolymers, respectively.

3. Results and discussions

3.1. Mechanical properties

In this work, our main focus is the effect of interfacial adhesion on the impact strength of immiscible PP/PETG blends compatibilized with triblock copolymers, thus composition of PP/PETG is fixed 70/30 by weight, and SEBS, SBS, SIS copolymer were added to PP/PETG blends at 1, 3, 5 wt%, respectively. Fig. 2 shows the Izod impact strength of PP/PETG blends compatibilized by three different kinds of triblock copolymers with different contents. The addition of SIS causes a remarkable increase in impact strength. By the addition of 5% SIS copolymer, the Izod impact strength increases from only 3.11 KJ/m^2 to 15.65 KJ/m^2. About 5 times enhancement of impact strength as that of the uncompatibilized blends and 3 times as that of pure PP has been achieved. To exclude the possible effect of SIS itself on increase of impact strength, PP was blend directly with SIS and the change of impact strength of the PP is also presented in Fig. 2. One observes that the Izod impact strength cannot be improved by simply adding SIS copolymer to pure PP. That's to say, the largely improved impact strength of PP/PETG blends by adding SIS should be only attributed to the compatibilization of SIS, not to the SIS rubber toughening effect. On the other hand, by using SBS copolymer, the Izod impact strength increases from 3.11 KJ/m^2 to 9.25 KJ/m^2 (seen in Fig. 2). The effect of SBS on impact strength is less effective than that of SIS. While the change of impact strength of PP/PETG blends by adding SEBS is not obvious, only slightly increase of Izod impact strength is observed up to 5 wt% SEBS.

The tensile properties of PP/PETG/compatibilizers blends are shown in Fig. 3. From the stress–strain curves, one can find the elongation at break of uncompatibilized PP/PETG blend is very low about 10%. The original PP has a very large elongation of about 400–500%, the sharp decrease of elongation by adding PETG is due to the poor miscibility between them. By adding SEBS, the yield strength of the blends does not change obviously. However, by adding SBS and SIS the yield strength of the blends increases with the increasing compatibilizers contents. The yield strength of the blends with SBS and SIS are enhanced from 33.6 to 39.6 and 37.6 MPa, respectively. And, the elongation at break of all compatibilized blends is improved. As we've seen above, SIS and SBS show obvious effect of compatibilization on PP/PETG blends. Especially, SIS can significantly improve the Izod impact strength of PP/PETG blends and tensile ductility as well.

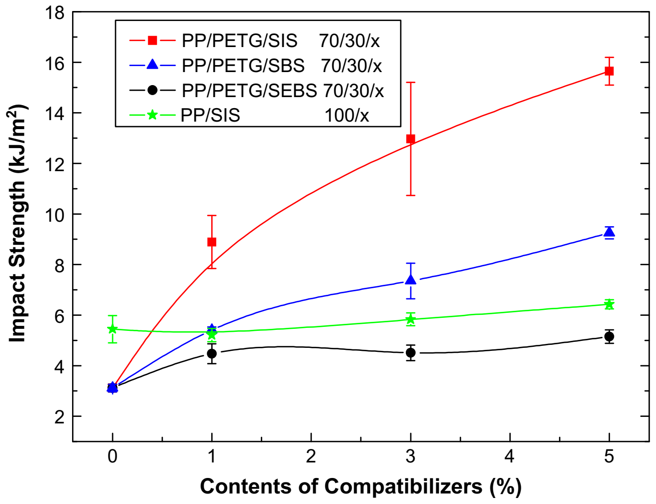

Fig. 2. Izod Impact strength of PP/PETG/Compatibilizers blends via compatibilizers contents.

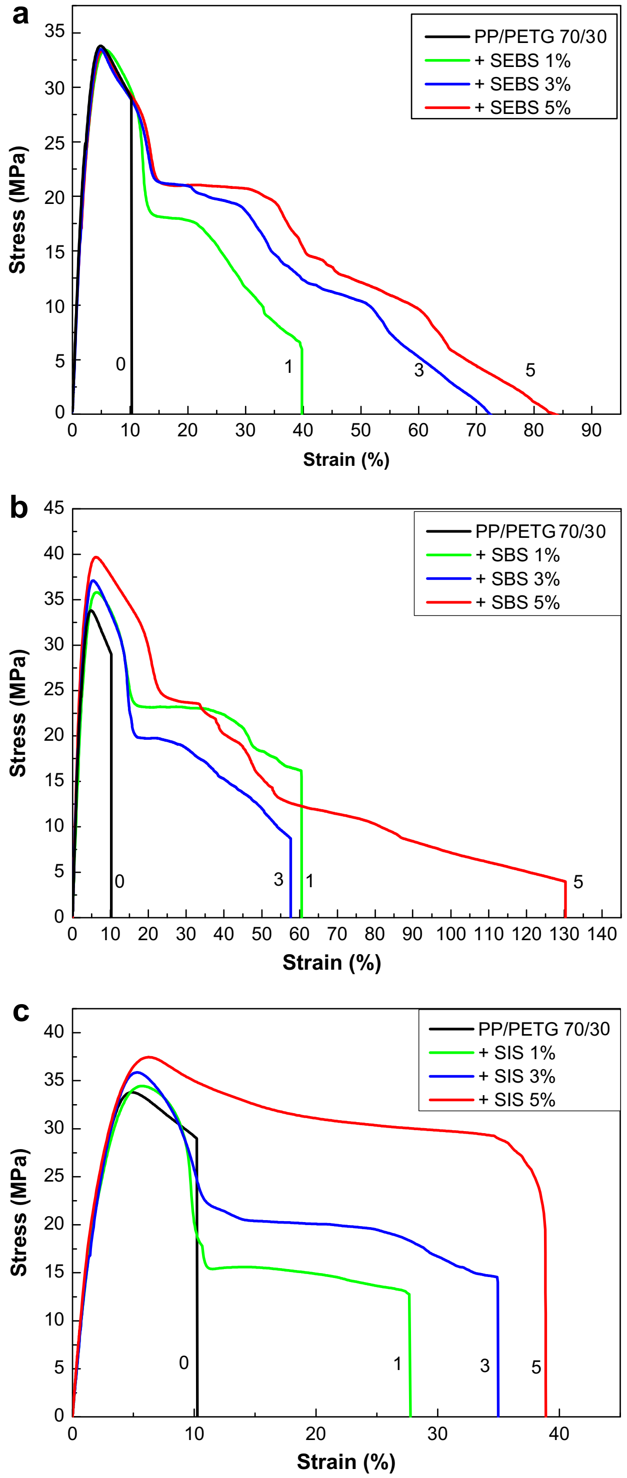

Fig. 3. Stress–strain curves of PP/PETG 70/30 blends compatibilized by various triblock copolymers. (a) SEBS; (b) SBS; (c) SIS. The numbers beside the curves represent the contents of compatibilizers.

3.2. Phase morphology

In our recent work [5], recycled PETG plastic was employed to toughening ABS resin for its fiber dispersed structure. We speculate that the mechanical properties of PP/PETG blends compatibilized by suitable compatibilizers can be also enhanced if this microfibrillar structure is obtained. Since different effect on Izod impact

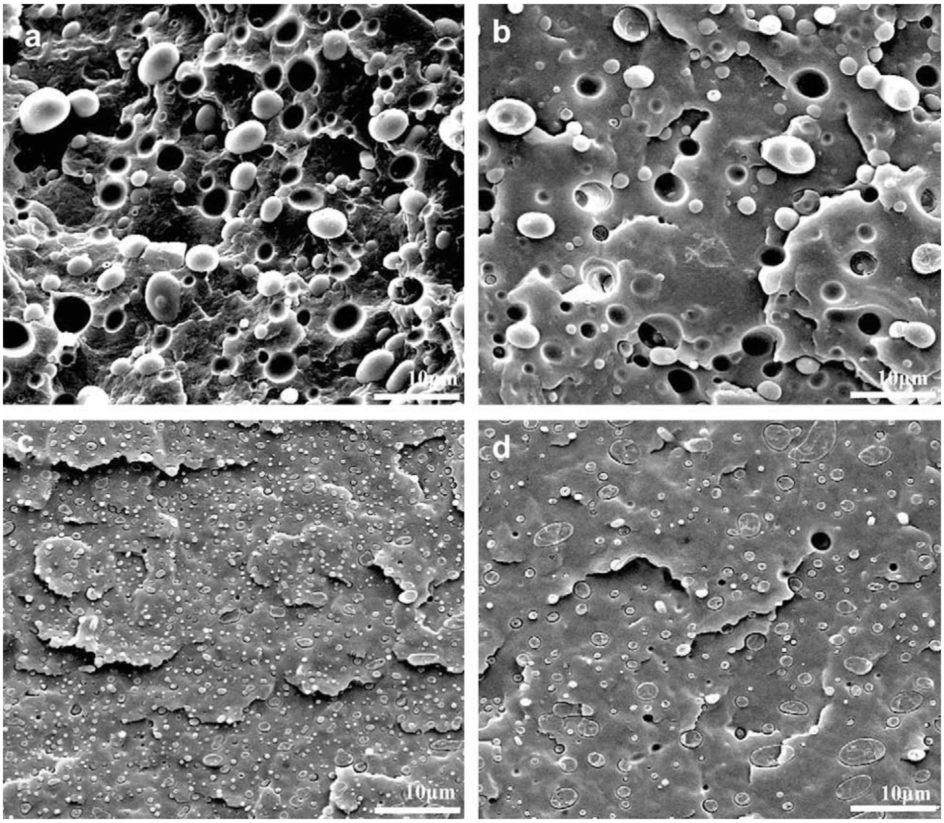

Fig. 4. The cryo-fractured surface of the PP/PETG 70/30 blends (a) uncompatibilized; (b) compatibilized by 5 wt% SEBS; (c) compatibilized by 5 wt% SBS, (d) compatibilized by 5 wt% SIS.

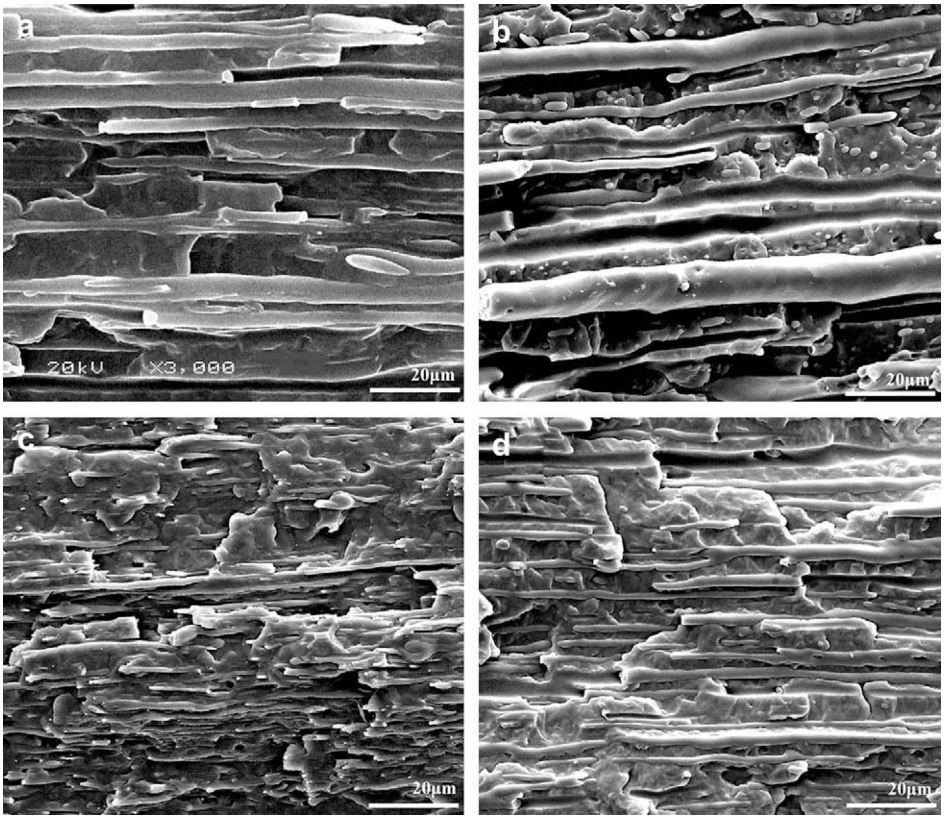

Fig. 5. The cryo-fractured surface of the PP/PETG 70/30 blends parallel the flow direction (a) uncompatibilized; (b) compatibilized by 5 wt% SEBS; (c) compatibilized by 5 wt% SBS, (d) compatibilized by 5 wt% SIS.

strength and tensile properties was found in PP/PETG systems by using different copolymers, SEM experiments were carried out to understand the relationship between the morphology and mechanical properties. Fig. 4 shows the cryo-fracture surfaces of uncompatibilized blend and the blends containing 5% compatibilizers. The images of uncompatibilized blend and the blend containing SEBS present coarse morphology and poor adhesion (seen in Fig. 4(a) and (b)). The phase domain sizes of dispersed phase are about 1–3 μm. The morphological observation of PP/PETG blend with 5% SEBS indicates poor compatibilization effect of SEBS, which is well corresponded to above the poor impact strength and the low tensile ductility. One expects a strong interfacial interaction and a smallest domain size in SIS compatibilized blend since it shows the largest improvement of impact strength. However, observed from Fig. 4(c) and (d), for PP/PETG blend compatibilized by SIS a larger phase domain size is seen compared with the blend compatibilized by SBS. The phase domain size of the blend with 5% SIS is about 0.5–2 μm, while the phase domain size of the blend with 5% SBS are more uniform, about 0.1–1 μm. On the other hand, the interfacial adhesion of the blend modified by SBS and SIS copolymer shown in Fig. 4(c) and (d) is much better than that of the blends unmodified or modified by SEBS, for the interface is obscure. Fig. 5 shows SEM images of the cryo-fracture surfaces that parallel to the flow direction. These are all microfibrillar dispersed structure. The PETG fibers are oriented along the flow direction. One observes the fibers in the blends modified with SBS and SIS copolymers have much smaller diameters. The interaction between fibers and matrix of blend compatibilized by SBS seems better than SIS and SEBS, for its fibers are embedded in matrix, while fibers in SEBS and SIS modified blends are exposed out of matrix. Generally speaking, adding better compatibilizer always offers better interfacial adhesion, smaller phase domain size and better mechanical properties. However, our observation indicates that not SIS but SBS is the best compatibilizer for PP/PETG blends, in terms of the domain size and interfacial interaction. This result arouses our interesting and the interfacial interaction will be further investigated by melt rheometry and contact angle measurements.

Table 2
Contact angle and surface tension results of PP, PETG, SEBS, SBS, SIS.

Sample	Contact angle (°)			Surface tension (mN/m)	
	Water	Diiodo-methane	Total (γ)	Dispersion component (γ^d)	Polar component (γ^p)
iPP	95.7 ± 8.6	40.1 ± 3.2	40.04	39.79	0.26
PETG	80.2 ± 2.3	34.7 ± 4.1	48.07	39.65	8.42
SEBS	90.4 ± 3.5	44.3 ± 2.0	40.73	35.76	4.97
SBS	79.4 ± 3.0	29.5 ± 1.7	50.11	41.67	8.44
SIS	82.4 ± 7.4	29.8 ± 3.2	48.79	41.62	7.17

3.3. Melt rheometry

Shear frequency dependence of the complex viscosity is shown in Fig. 6, for the as-prepared blends containing different kinds and amounts of compatibilizers. It can be seen that at low frequency range (0.005–1 rad/s), the viscosity of the blends increases with increasing of compatibilizer for all the three systems (seen in Fig. 6 (a)–(c)), but to different degrees. This kind of phenomenon has already been studied by several researchers for different polymer blends [6–12]. The increase of viscosity at low frequencies can be ascribed to a relaxation process of the minor phase when slightly deformed [13], and it can be used to evaluate the interfacial tension between the phases of the blend by using emulsion models [6–12]. The largest increase is seen for the blend compatibilized with SBS

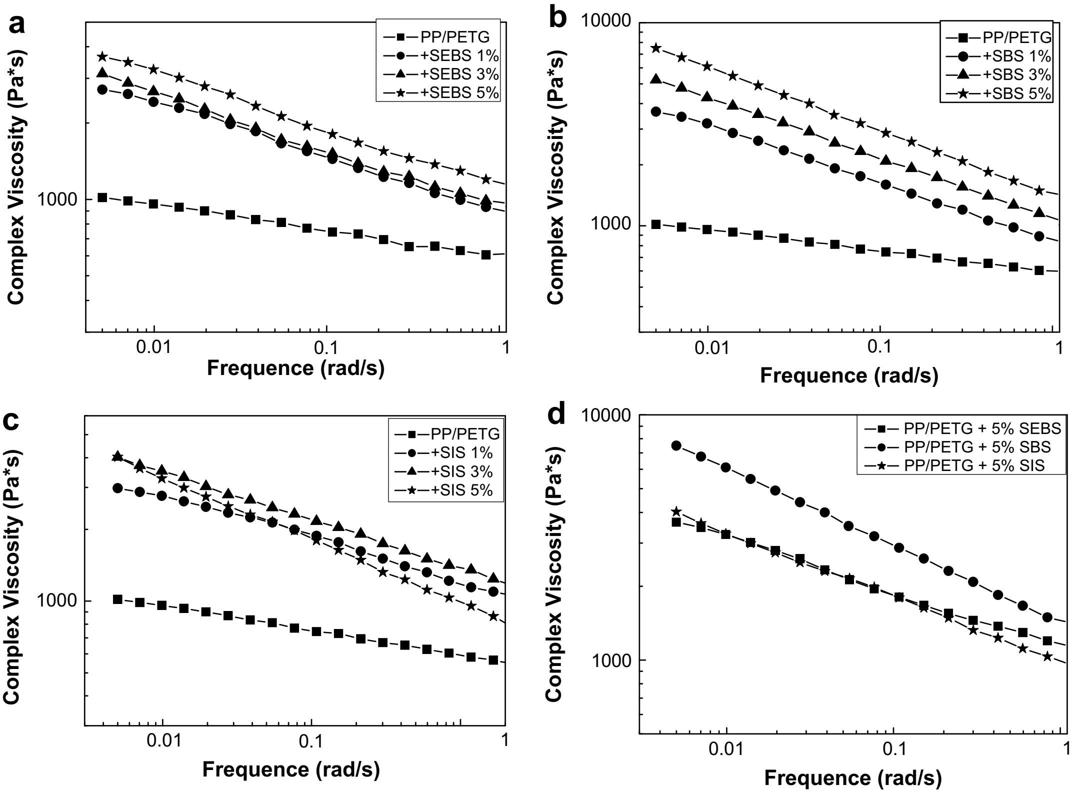

Fig. 6. The complex viscosity vs. shear frequency curves for the PP/PETG modified by different contents of copolymers, (a) SEBS; (b) SBS; (c) SIS. (d) The complex viscosity comparison by the addition of different copolymers, the copolymer contents are all 5%.

Table 3
The value of interfacial tension (γ_{AB}) and work of adhesion (W_{AB})of PP/PETG/SEBS(SBS, SIS) blends.

Possible pair	Interfacial tension (γ_{AB}) (mN/m)	Work of adhesion (W_{AB}) (mN/m)
PP/SEBS	3.06	77.71
PP/SBS	5.76	85.78
PP/SIS	4.71	84.12
PETG/SEBS	0.55	88.25
PETG/SBS	0.15	98.15
PETG/SIS	0.074	96.78

(see the comparison in Fig. 6(d)). Thus the result obtained from melt rheometry indeed indicates a stronger interfacial interaction in this system. For blends compatibilized with SIS, one observes a lever off of viscosity at addition of 5 wt% SIS, suggesting saturated effect at this concentration, but a continuous increase of viscosity for the other two systems, no saturation is observed within the compatibilizers content investigated.

3.4. Contact angle measurements

To better understand the different compatibilization effects of compatibilizers, interfacial tension (γ_{AB}) and work of adhesion (W_{AB}) consideration should be taken into account. For this reason, the contact angles measurements with water and diiodomethane were carried out, and the results are listed in Table 2. The surface tension, dispersion and polar components of the materials can be calculated from the contact angle data by using the following two equations (Eq. (1) for water and Eq. (2) for diiodomethane) according to Wu [14]:

$$(1+\cos\theta_{H_2O})\gamma_{H_2O} = 4\left(\frac{\gamma^d_{H_2O}\gamma^d}{\gamma^d_{H_2O}+\gamma^d}+\frac{\gamma^p_{H_2O}\gamma^p}{\gamma^p_{H_2O}+\gamma^p}\right) \quad (1)$$

$$(1+\cos\theta_{CH_2I_2})\gamma_{CH_2I_2} = 4\left(\frac{\gamma^d_{CH_2I_2}\gamma^d}{\gamma^d_{CH_2I_2}+\gamma^d}+\frac{\gamma^p_{CH_2I_2}\gamma^p}{\gamma^p_{CH_2I_2}+\gamma^p}\right) \quad (2)$$

in which $\gamma = \gamma^d + \gamma^p$, $\gamma_{H_2O} = \gamma^d_{H_2O} + \gamma^p_{H_2O}$, $\gamma_{CH_2I_2} = \gamma^d_{CH_2I_2} + \gamma^p_{CH_2I_2}$, γ is surface tension, d is dispersion component and p is polar component, $\theta_{H_2O}$and $\theta_{CH_2I_2}$ are contact angles of the polymer with water and diiodomethane, respectively. The numerical values used are $\gamma^d_{H_2O} = 22.1$ dyn/cm; $\gamma^p_{H_2O} = 50.7$ dyn/cm; $\gamma^d_{CH_2I_2} = 44.1$ dyn/cm; $\gamma^p_{CH_2I_2} = 6.7$ dyn/cm. The values of surface tension, dispersion and polar components are also shown in Table 3. Then the interfacial tension can be calculated from surface tension by using the geometric mean equation of Wu [15]:

$$\gamma_{AB} = \gamma_A + \gamma_B - 2\left(\gamma^d_A\gamma^d_B\right)^{1/2} - 2\left(\gamma^d_A\gamma^d_B\right)^{1/2} \quad (3)$$

and the work of adhesion can be calculated using following equation [16]:

$$W_{AB} = 2\left(\gamma^d_A\gamma^d_B\right)^{1/2} + 2\left(\gamma^p_A\gamma^p_B\right)^{1/2} \quad (4)$$

The results are summarized in Table 3. The lower the interfacial tension value, the higher the work of adhesion values will correspond to a stronger interaction between the components. Observed from Table 3, the contrast of interfacial tension values between PP and the compatibilizers is subtle. However the order of interfacial tension values between PETG and compatibilizers, work of

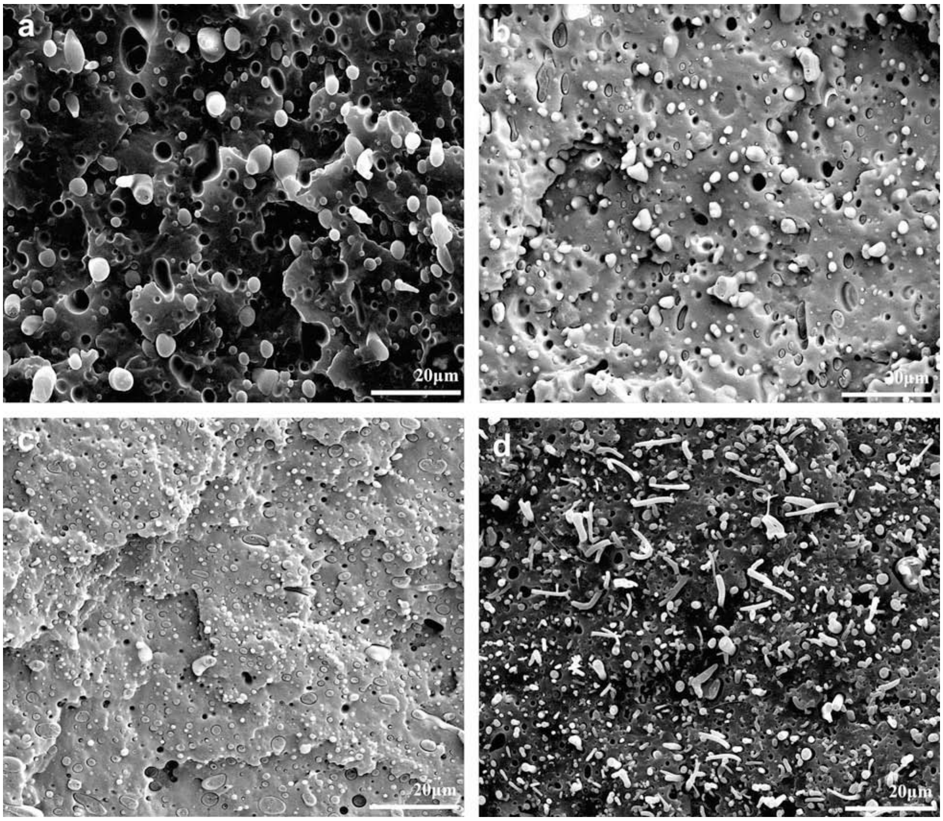

Fig. 7. The impact fractured surface of the PP/PETG 70/30 blends (a) uncompatibilized; (b) compatibilized by 5 wt% SEBS; (c) compatibilized by 5 wt% SBS, (d) compatibilized by 5 wt% SIS.

adhesion values between PP/PETG and compatibilizers are all accord with the order of compatibilization effect that we get from SEM microimages and melt rheology. All these results together lead us to draw a safety conclusion that SBS shows the best compatibilization effect and strongest interfacial adhesion, SEBS shows the worst, and SBS lies between them.

4. Discussion

From these morphology, melt rheology and contact angle measurements, it can be concluded that the blends compatibilized with SBS have smallest domain size and strongest interfacial interaction, the blends compatibilized with SEBS have largest domain size and poorest strongest interfacial interaction, while the one compatibilized with SIS shows a moderate domain size and moderate interfacial interaction, among the three compatibilized PP/PETG blends. And this can be further understood from the molecular characteristic of the compatibilizers (see in Table 1 and Fig. 1) and the solubility parameters. In this work, the compatibilized blends can be treated as A/C-b-D/B compatibilization model, C-b-D is the block copolymer as compatibilizer containing two groups which are different from matrix A and dispersed phase B. The difference between these copolymers is that they contain various rubber blocks. The solubility parameter (σ) of styrene block in three block copolymers (PS) 18.6–20.16 [17] is approximate to that of PP 18.8–19.2 [17] and PETG 21 [18]. It may mean that PS block can have good interaction with PP or PETG phase. The rubber phases of the triblock copolymer are found to have σ values closer to that of PP than PETG. Among the three rubber phases of triblock copolymer, polybutadiene block in SBS (PB) shows highest σ value 17.3 [17], while poly(ethylene-co-1- butene) (EB) shows the lowest σ value 15.7 [19], and polyisoprene block in SIS (PI) shows a intermediate σ value 16.2–16.7 [17]. The rubber phases take the much greater proportion of triblock copolymer (see in Table 1), so the gap of σ values between rubber phase and PP may produce an important impact on the compatibilization effect of these triblock copolymers. On the other hand, the higher σ value of rubber phase is, the smaller the gap between σ values of rubber phase and PP is. Consequently, it is believed that PP has best adhesion with PB (SBS), worst for EB (SEBS) and moderate for PI (SIS). And it also lead us to believe that SBS presents best compatibilization effect, SEBS the worst, while SIS lies between them. It should be also noted that the molecular weight and block proportion of the three block copolymers are different. Whether these factors play an important role in the compatibilization effects of these block copolymers? In A/A-b-B/B model, Kramer et al. [20] proved that only if the molecular weight of each phase of block copolymer is higher than that of the polymer which is miscible with the phase, the compatibilizers can significantly enhance the compatibility of the blend. Stadler et al. [21,22] investigated A/C-b-D/B blends by using TEM and DMA and found that the molecular weight of C-b-D copolymer did not influence the compatibilization effect obviously. In our work, all the molecular weight of block copolymers is much lower than that of PP, and the compatibilization model is A/C-d-D/B, so we consider the molecular weight does not play a significant role in the compatibilized blends.

However, the result from impact strength test indicates that addition of SIS causes a considerable increase in Izod impact toughness, but only slightly improved toughness is observed for blends compatibilized with SEBS, and the effect of SBS on improving the impact toughness lies in between. In order to reveal the relationship between interfacial interaction and toughening effect of the copolymers, impact fractured surface SEM micrographs were taken and compared (seen in Fig. 7). It can be seen that, the fracture surface of uncompatibilized blend is flat, part of PETG fibers are broken off. The others are drawn out and separated from matrix only left black holes. The impact fractured surface of SEBS compatibilized blend is similar to that of uncompatibilized blend. For the blend compatibilized with SIS, one observes lots of PETG fibers debonding from matrix and drawn out of surface, and the matrix is yielded and deformed seriously. However, In the case of SBS, the PETG fibers are mainly broken off without obvious debonding from matrix. (seen in Fig. 7(c)). It is believed that the debonding of fibers from the matrix and the course that fibers are drawn out of matrix, should be responsible for the best impact toughness. That is to say, the poor interfacial adhesion will result in an easier debonding of fibers but also a poor dispersion and big domain size of the fibers. Very strong interfacial adhesion will result in a good dispersion and small domain size of the fibers, but a difficult debonding of fibers. Thus a moderate interfacial adhesion is needed for both good the dispersion and easier debonding of fibers. Similar observation has been reported by many researchers on PP and inorganic fillers composites [23–26]. Thio et al. [26] had investigated the effect of interfacial adhesion strength on the mechanical properties of PP/glass particles composites. They found that impact toughness increased with weaker adhesion. They pointed out that the easier debonding which results from weaker adhesion could cause more extensive amount of plasticity in the composites during deformation. In our work, we find that, for

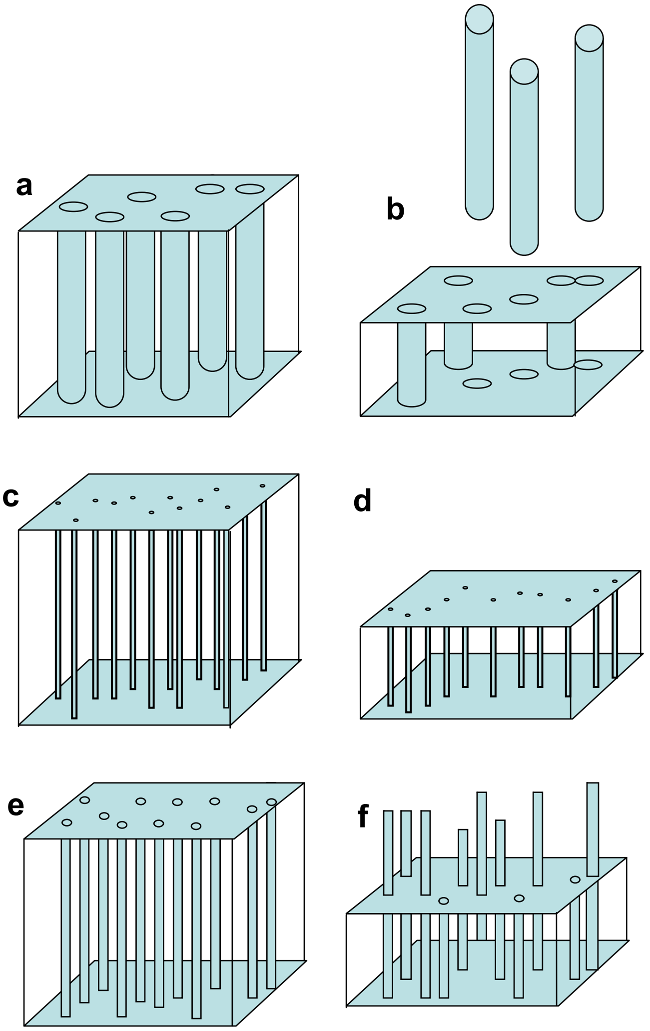

Fig. 8. (a),(c),(e) are blends compatibilized by SEBS,SBS,SIS, respectively. (b),(d),(f) are the impact fractured blends compatibilized by SEBS,SBS,SIS respectively.

purpose of toughening the desirable interfacial adhesion should be moderate, neither too strong nor too weak. The schematic representation of toughening mechanism for PP/PETG/compatibilizers blends is shown in Fig. 8. In these cubes, the columns represent for PETG dispersed fibers, the outline of the columns represents for the interface, the thicker the outline is, the stronger the adhesion is. As presented in the Fig. 8(a) and (b), PETG fibers diameter is the biggest of the three and the adhesion is weakest. When the blend with 5 wt% SEBS is fractured in impact test, the interfacial adhesion is so weak that the fibers will be easily debonding and drawn out of matrix without absorbing much energy or broken off. In contrast, it can be seen in Fig. 8(c) and (d), PETG fibers diameters are the smallest with strongest adhesion. When the blend with 5 wt% SBS is fractured, the strongest adhesion makes it hard to debond from matrix. Most of fibers are broken off. As for blend with 5 wt% SIS, as shown in Fig. 8(e) and (f), the fiber diameter and adhesion of blend are both in the middle of the three. Fractured in impact test, the fibers are debonded from the matrix and are partially drawn out of matrix. Debonding and drawn out of matrix with the moderate adhesion cause PP/PETG/SIS blend dissipating much more energy than the others. This could be the main reason that the largest improvement of impact strength is observed in the blends compatibilized with SIS.

5. Conclusion

PP/PETG blends compatibilized by three different triblock copolymers were achieved with distinct impact toughness. By adding SIS copolymer, the Izod impact strength of the blend increases by five times. In the case of SBS, only two times improvement in toughness is obtained. SEBS only slightly improves the toughness of the blend. Elongation at break is also enhanced by the addition of the three compatibilizers. The yield strength of the blends with SEBS did not change obviously with SEBS contents, while that of the blends with SBS and SIS was both enhanced with the increasing compatibilizers contents. The results from phase morphology, melt rheometry investigations and contact angle measurements indicate that the blend with SBS has smallest phase domain sizes and strongest interfacial adhesion, the blend with SEBS shows coarse morphology and worst adhesion, the blend with SIS has a moderate domain size and interfacial interaction. The SEM micrographs of the impact fractured surface give answer to the contradictory of impact toughness and the interfacial interaction. For the blends compatibilized by SIS, the moderate adhesion resulting in an easier debonding of the fibers from matrix and consequently drawn out of matrix, which significantly dissipated more energy than the other adhesion condition. And for the blends compatibilized by SEBS, the adhesion and dispersion are too bad, although the PETG fibers could be easily debonded and be drawn from matrix when impacted, the absorbing energy in the course are very limited. For the blends compatibilized by SBS, the strong adhesion makes the fibers hard to debond from matrix, and not much energy is dissipated in the course of fibers breaking off.

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