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Effects of a compatibilizing agent on the morphology, interface and mechanical behaviour of polypropylene/poly(ethylene terephthalate) blends

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Abstract

Three maleic anhydride-grafted-polypropylene (PP) derivatives [*N*, *N*-dihydroxyethyl monomaleic amide (C-2A), octodecyl monomaleate (C-3), and 2-(*N*, *N*-dihydroxyethylamino)ethyl monomaleate (C-4)] were prepared by melt grafting and utilized to compatibilize polypropylene/poly(ethylene terephthalate) (PP/PET) blends. The resulting blends were characterized by means of scanning electron microscopy, thermal analysis and testing of mechanical properties. The results show the compatibilizing effects of the three PP grafts are very different and strongly dependent on the functional groups present. Compatibilizer C-4 produced the finest dispersed phase morphology, whereas C-3 showed little compatibilizing effect. Substitution of 40 wt.% of C-2A with a *tert*-butyl phenolic resin further improved the compatibilizing effect and resulted in much finer domains of the dispersed phase. Modulated-temperature differential scanning calorimetry (M-TDSC) determination revealed that the glass transition (T_g), crystalline temperature (T_c), melting temperature (T_m), and enthalpy of crystallization (ΔH_c) of the PET component all declined to some extent by comparison with neat PET. The increment of heat capacity at the glass transition, ΔC_p, was found to be changed by the compatibilizers and displayed a trend in very good agreement with that of the morphology, as well as with the mechanical properties. The decrease in the ΔC_p value may be used as a new parameter for quantitative estimation of the extent of compatibilization, as the decrease in ΔC_p is related to the increase of interface content. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Polypropylene/(polyethylene terephthalate) blends; Compatibilization; Interface

1. Introduction

Blending of polymers is an effective means of developing new organic materials from existing ones. This method is very important and can be applied, as it is suitable for many polymer systems [1]. However, most polymer pairs are essentially immiscible. Blending of two or more polymers usually results in a multiphase blend, instead of a homogeneous material [2]. The morphology and interfaces between microphases are predominant influences in determining ultimate properties of these multiphase blends [3]. Therefore, for effective blending, these factors must be under control in order to acquire reproducibly in the properties of the blend.

In the past two decades, many researchers have focused on the control of morphology and interfaces of immiscible polymer blends in order to improve their compatibility. It is now well known that copolymers, especially block and graft copolymers, are effective for this purpose [3–5]. These copolymers, which are called compatibilizers when used for this purpose, can be pre-formed copolymers or formed in situ during melt blending through interfacial chemical reaction of the polymeric components. Usually the compatibilizer concentrates at interfaces during blending, and plays the roles of reducing interfacial tension, preventing coalescence and strengthening interface adhesion [6]. As a result, the domain size decreases and the mechanical properties improve.

Polypropylene (PP) is one of the most important and widely used thermoplastics. The modification of PP for engineering applications has received great attention in past decades in both academic and commercial circles. The blending of PP with engineering thermoplastics has been an effective way to improve the properties of PP. For example, PP/polyamide blends are intensively investigated in the literature [7]. There has been, however, very limited research concerned with blends of PP with poly(ethylene

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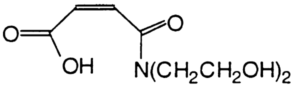
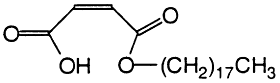
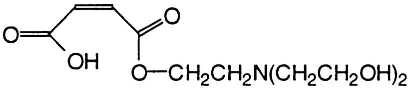
Table 1
Structure of MAH derivatives grafted onto the PP compatibilizers

Compatibilizer code	MAH derivatives	Extracted MAH derivatives (wt.%)[a]	Grafted MAH derivatives (phr)
C-2A		20.5	6.36
C-3		30.2	5.58
C-4		30.4	5.57

[a] Calculated from weight loss after extraction with a mixture of water and ethanol.

terephthalate) (PET). Bataille et al. [8] reported that PP/PET blends without compatibilizer exhibited weak interactions between the two phases, and, hence, the mechanical properties were poorer than both for neat PP and for PET. Xanthos et al. [9] found that the addition of PP grafted with maleic anhydride (MAH) or acrylic acid (AA) to PET/PP blends resulted in finely dispersed phases, showing the grafted PPs were able to compatibilize these blends. More recently, Heino et al. [10] investigated the compatibilization of PET/PP blends with poly[styrene-b-(ethylene-co-butylene)-b-styrene] (SEBS) grafted with MAH (SEBS-g-MAH) or glycidyl methacrylate and demonstrated that the addition of the functionalized SEBS yielded a finer dispersion of the minor phase and improved interfacial adhesion. Lepers et al. [11] studied the relative role of coalescence and interfacial tension during compatibilization of PET/PP blends. They found that the compatibilizer, SEBS-g-MAH, had dual roles: the reduction of interfacial tension and the prevention of coalescence of the dispersed phase.

Although many papers have discussed effects of compatibilization on morphological and mechanical properties of immiscible blends, details of the interfaces in these blends are still not clear because of the lack of quantitative data. For example, it is widely accepted that the improvement of mechanical properties of a compatibilized blend results from the improved interfacial adhesion. Few reports, however, have quantified the values of interfacial adhesion because this is difficult to measure. Recently, Hourston and his co-workers [12–15] have developed a new method for determination of the weight fraction of interfaces in multi-component materials by means of modulated-temperature differential scanning calorimetry (M-TDSC). This method uses the increment of heat capacity at the glass transition temperature to quantify the interfacial content of a multiphase blend, and has been successfully applied to measure interfacial contents of a poly(methyl methacrylate)/polyepichlorohydrin blend and other thermoplastic blends [12], structured polymer latices [13] and interpenetrating polymer networks [14]. This new technique makes it possible to achieve a fuller understanding of interfaces in polymer blends.

In this article, we have studied the compatibilization of PP/PET blends by using PP grafted with MAH derivatives and a *tert*-butyl phenolic resin as compatibilizers. The main objective is to relate the extent of compatibilization to the morphology, interface and mechanical properties. Also, a new method to estimate quantitatively the effectiveness of a compatibilizer by comparison of the interface composition of the uncompatibilized and compatibilized polymer blends is presented.

2. Experimental

2.1. Materials

Polypropylene (grade: PP 1600, MFI = 7.5 g/10 min) and Poly(ethylene terephthalate) (PET, intrinsic viscosity = 0.68 g/dl) used in this work were produced by the Yanshan Petroleum Chemical Group Co. and Fushan Polyester Chip Plant (China), respectively. The PP grafted MAH derivatives (their chemical structures are listed in Table 1) were prepared by reactive extrusion in our laboratory. *tert*-butyl phenolic resin (trade name: Phenolic 2402) was purchased from the Guangzhou Chemical Materials Company.

2.2. Processing

2.2.1. Melt grafting of PP with MAH derivatives

The melt grafting of PP with the MAH derivatives was

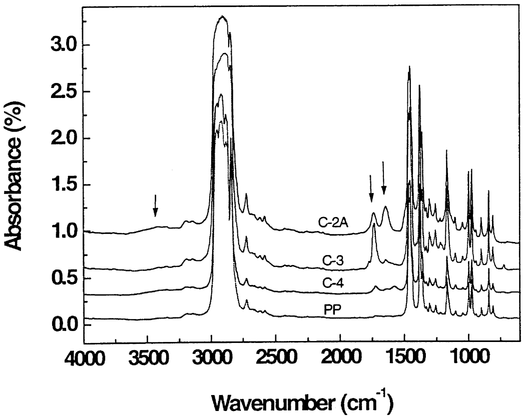


Fig. 1. FTIR spectra of PP and the grafted PP samples.

carried out by reactive extrusion using a co-rotation twin-screw extruder with a screw diameter of 35 mm and *L*/*D* ratio of 40. The screw rate was set at 30 rpm. The barrel of the extruder had 8 temperature-control zones and their temperatures were set at (from feeding section to die) 160, 190, 200, 210, 220, 220, 210, and 200°C. The composition for grafting is: PP/MAH derivatives/dicumyl peroxide = 100/8/0.22 (weight ratio). All ingredients were first premixed in a high-speed stirrer to ensure uniform composition before feeding to the extruder. The resulting grafted PP pellets were used directly as compatibilizers without the removal of any unreacted MAH derivatives.

2.2.2. Extrusion blending of PP and PET

Five blends containing PET at 20 wt.%, PP at 75 wt.%, and compatibilizer at 5 wt.% were compounded in the same twin-screw extruder running at 30 rpm. The temperature settings of the barrel were: 160, 260, 280, 290, 290, 290, 270, and 260°C. Before blending, the compositions were dried in a vacuum oven overnight at 120°C and used immediately. The extrudates were cooled by passing through a water bath and then pelletized. The pelletized blends were again dried in a vacuum oven at 120°C for 10 h. The dried blend pellets were made into sheets of 4 mm thickness by compression moulding at 165°C and then cut into specimens according to the corresponding ASTM standards.

2.3. Characterization

2.3.1. Infrared spectroscopy

PP grafted MAH derivatives, the compatibilizers, were pressed into thin films by compression moulding in a hot press. The resulting films were extracted with a mixture of ethanol (70 vol.%) and water (30 vol.%) for two weeks in order to remove the unreacted MAH derivatives and were then dried before carrying out FTIR analysis. A Mattson 3000 FTIR spectrometer was used.

2.3.2. Scanning electron microscopy (SEM)

The morphologies of PP/PET blends were observed by SEM. Impact fracture surfaces of the blends were imaged using a Cambridge Instruments Stereoscan 360 scanning electron microscope.

2.3.3. Thermal analysis

Analysis by M-TDSC was performed using a model 2920 calorimeter from TA Instruments. The running conditions were: oscillation amplitude: 1.0°C; oscillating period: 60 s; heating rate: 3°C/min; and N_2 flow rate: 60 ml/min. All samples were first heated to 280°C and then quenched in liquid nitrogen so as to prevent the PET component from crystallizing and to ensure the same thermal history for all samples. M-TDSC data were processed by using of the GRAPHWARE software of TA Instruments.

Dynamic mechanical thermal analysis (DMTA) was conducted on a model Mk II DMTA instrument from Rheometrics Scientific. The three-points bending mode was selected. The heating rate was set at 3°C/min and the frequency at 10 Hz.

2.3.4. Mechanical testing

Mechanical tests were performed according to corresponding ASTM standards. Tensile strength and three-point flexural strength were measured with an Instron Materials Tester. Charpy impact strength was determined with a Monsanto Tester. All the reported results are the average of at least five measurements for tensile and flexural determinations, and ten for impact tests00.

3. Results and discussion

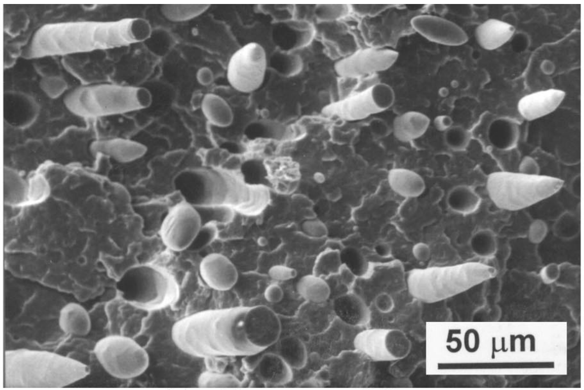
3.1. FTIR spectroscopy analysis of the compatibilizers

It is seen from Fig. 1 that all of the grafted PP samples show absorbance bands at 3440 to 3500 and 1733 cm^{-1} assigned to hydroxyl and carbonyl groups, respectively, indicating the grafting of the MAH derivatives onto the PP main chains. The amounts of grafted MAH derivatives were calculated by extracting the unreacted parts with a mixture of ethanol (70 vol.%) and water (30 vol.%). Results are listed in Table 1.

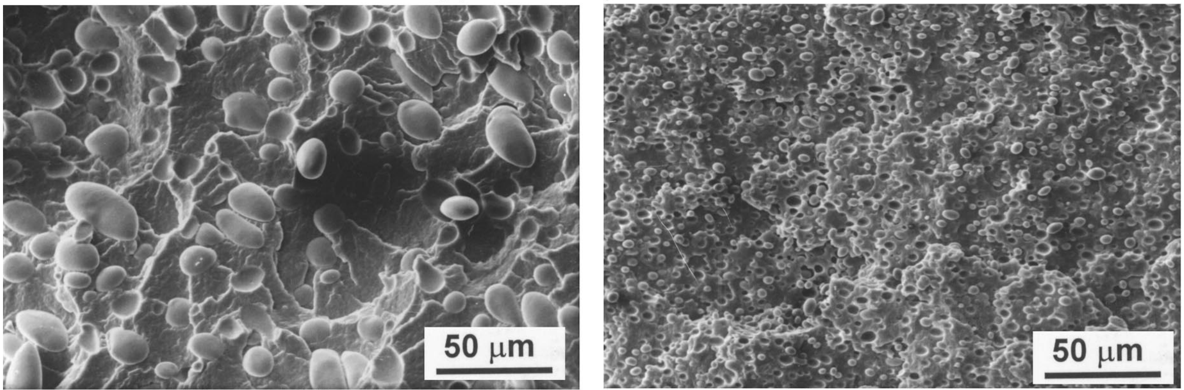
3.2. The influence of compatibilization on morphology

The morphologies of PP/PET blends compatibilized with the different compatibilizers are presented in Fig. 2. It is seen that these different compatibilizers result in entirely different morphologies. Without compatibilizer, the blend (sample 12-4) shows a dispersed PET phase with irregular shapes and sizes, and even a large fraction of the domains is fibre-like (Fig. 2(a)). The addition of compatibilizers produced regular shaped and relative uniformly sized PET domains. The PET domain sizes strongly depend upon the compatibilizers used.

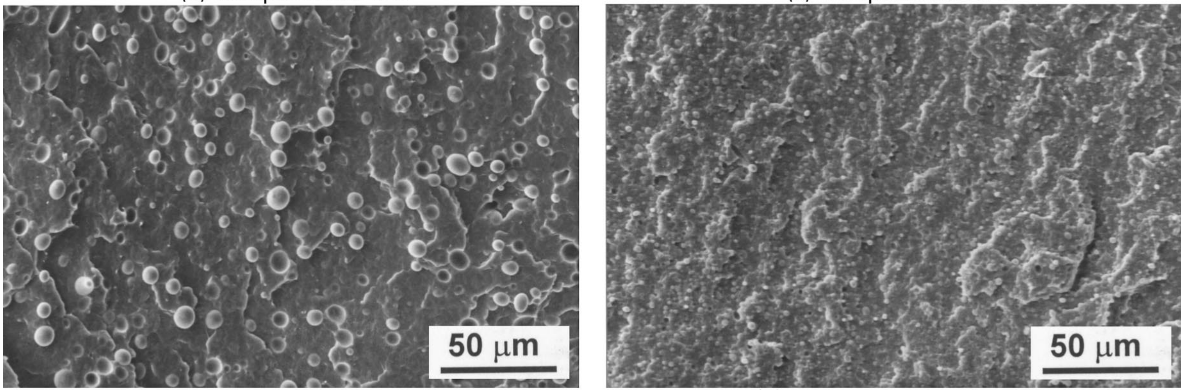
It is widely accepted that a compatibilizer has two main roles in the control of morphology of a blend, that is,



(a) without compatibilizer



(b) compatibilizer: C-3
(c) compatibilizer: C-4



(d) compatibilizer: C-2A
(e) compatibilizer: C-2A/2402

Fig. 2. SEM micrographs of impact fracture surfaces of the PP/PET blends compatibilized with the three compatibilizers.

prevention of coalescence and reduction of interfacial tension [11]. The uniformity of shape and size of the PET domains caused by addition of compatibilizers is believed to be the result of reduction of coalescence because of the steric stabilization role of compatibilizers. In contrast, the change of PET domain sizes with the various compatibilizers is considered to be caused by the different extents of decrease in interfacial tension. For example, although blend 14-1 compatibilized with compatibilizer C-3 (see Table 1) shows a PET domain size of about 16 μm (Fig. 2(b)), which is almost the same as that of the uncompatibilized sample 12-4, the shapes of PET domains have higher regularity than the latter. This is because C-3, whose functional groups possess a long alkyl radical, is more compatible with PP than PET and has little interaction with PET. So, the main role of C-3 may be the prevention of coalescence. However, compatibilizers C-4 (Fig. 2(c)) and C-2A (Fig. 2(d)), both of which have two hydroxyl groups, produce much finer PET domain sizes. These hydroxyl groups can react with carboxyl end groups of PET or undergo transesterification with PET main chains during blending [8]. Both reactions lead to formation of graft copolymers of PP and PET. The latter accumulates at blend interfaces and reduces the interfacial tension. As a result, the blend domain sizes become smaller. It should be noticed that C-4 (Fig. 2(c)) produces finer domain sizes than C-2A (Fig. 2(d)). The cause is that C-4 contains an extra tertiary amine functional group. This tertiary amine group is beneficial to increase interactions

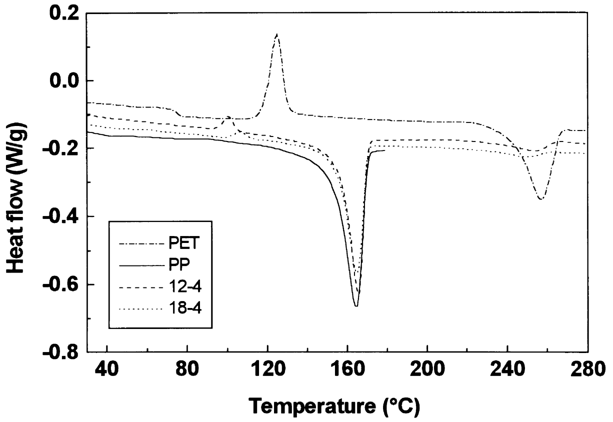


Fig. 3. M-TDSC thermograms for the PP/PET blends and the component polymers.

between the PP and PET phases because it increases the polarity of the compatibilizer and may form a salt with the carboxyl end groups of PET. The finest PET domain sizes (Fig. 2(e)) were obtained by compatibilization with C-2A and a *tert*-butyl phenolic resin. It is clear by comparison with Fig. 2(d) that the smaller domain sizes result from addition of the phenolic resin. This is, in our opinion, caused by the phenolic hydroxyl and hydroxymethyl groups of the phenolic resin. The former may form hydrogen bonds with main chain carbonyl groups of the PET, while the latter may transesterify with PET ester groups. Meanwhile, the latter may also condense with the hydroxyl groups of C-2A. Consequently, the interaction between two phases is strengthened, resulting in the remarkable reduction of interfacial tension and domain size of the dispersed phases.

From the aforementioned discussion, it can be seen that the functional groups of the grafted PP have a very strong influence on its compatibilizing effectiveness. The polarity and reactivity of the functional groups, as well as matching of the prospective reactive groups, are the dominant factors for compatibilizing effectiveness.

3.3. Thermal analyses

In addition to observing morphology changes, the effects of compatibilization on polymer blends can also be investigated by determination of their thermal properties. The M-TDSC results for neat PP and PET, for the uncompatibilized and for the compatibilized blends are shown in Fig. 3. It is seen that the melting peaks of PP in the blends are actually the same as that in pure state. All the melting temperatures are about 165°C, as listed in Table 2. These results are easy to understand if it is remembered that PP is the major phase in the blends. However, the melting enthalpies (ΔH_m) of PP components are slightly lower than that of neat PP (Table 2). The ΔH_m for neat PP is 130.2 J/g, which means a 62.3% degree of crystallinity according to the quoted value of 209 J/g for fully crystalline PP [16]. It is interesting that the changing trend in ΔH_m for PP component basically correlates to the morphology changes of the blends: the finer the dispersed phase, the lower is the ΔH_m value. These results, we believe, are related to the increase of interfaces in the blends, which leads to a decrease of weight fraction of the bulk PP. In contrast, for the PET component the melting and crystalline peaks move somewhat towards low temperatures, especially the crystallization temperatures. These are more obviously seen in Fig. 4; the enlarged and normalized parts of Fig. 3. The resulting data are listed in Table 3. In order to make it relatively comparable to those of the blends, the heat of crystallization (ΔH_c) of neat PET listed in Table 3 is one-fifth of its observed value, as PET is only one-fifth by weight in the blends. By comparing these data, it is clear that the blends uncompatibilized and compatibilized by grafted PP had similar ΔH_c values, which were slightly smaller than that of neat PP. However, for sample 18-4, which was compatibilized by the substitution of 40 wt.% of C-2A with a phenolic resin (2402), its ΔH_c value was very low, being less than half of the others. This dramatic decline of ΔH_c caused by the addition of the phenolic resin may be the result of reduction of the bulk PET fraction. This problem will be further discussed in the next part.

Table 2
M-TDSC data for the PP component in the PP/PET blends[a]

Sample	Compatibilizer	T_g (°C)	δ (mJ/g/°C)	T_m (°C)	ΔH_m (J/g)
PP	—	5	0[b]	165	104.1[c]
12-4	—	1	−13.9	166	93.0
14-1	C-3	1	−6.2	164	92.5
16-1	C-4	1	−8.8	166	89.6
18-2	C-2A	5	−3.4	165	96.3
18-4	C-2A/2402[d]	4	−15.6	165	85.5

[a] PP/Compatibilizer/PET = 75/5/20.
[b] The ΔC_p value is 58.3 mJ/g/°C.
[c] $0.8 \times \Delta H_m$ determined with neat PP.
[d] C-2A: 3.0 wt%, 2402: 2.0 wt%.

With respect to T_m values of the PET component, it appears that they are all somewhat lower than that of neat PET and dependent on blend composition. The data in Table 3 suggest that the T_m of the PET component is related to morphology of the blend: the larger the PET domain size, the higher is its T_m value. This result may originate from the effect of interfacial tension between the two phases. However, the crystallization temperatures, T_c, of the PET component in the blend moved to much lower values compared to neat PET, as seen in both Table 3 and Fig. 4b. For compatibilized systems, their T_c values were around 107°C, nearly 20°C lower than that of neat PET (125°C) determined here. For the uncompatibilized sample, the T_c was 101°C, a further 6°C lower than those of the compatibilized systems. The significant decline in T_c of the PET component may result from a PET nucleating effect by the PP component. Bourland [17] observed a similar phenomenon in his investigation of PET crystallization in the presence of different nucleating agents, including PP.

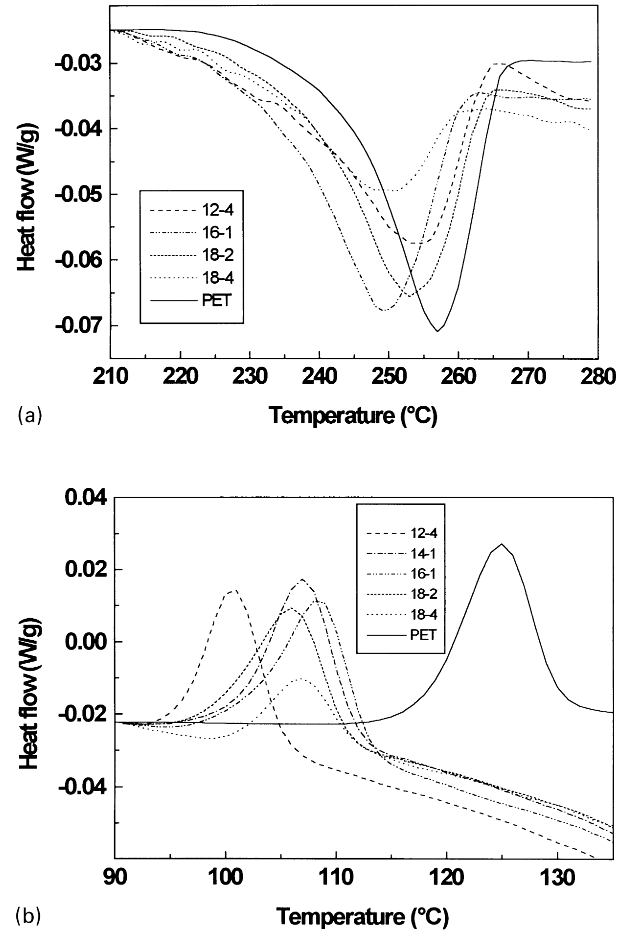


Fig. 4. (a) Melting peaks of the PET components in the blends and of the neat PET; (b) crystalline peaks of the PET components in the blends and neat PET.

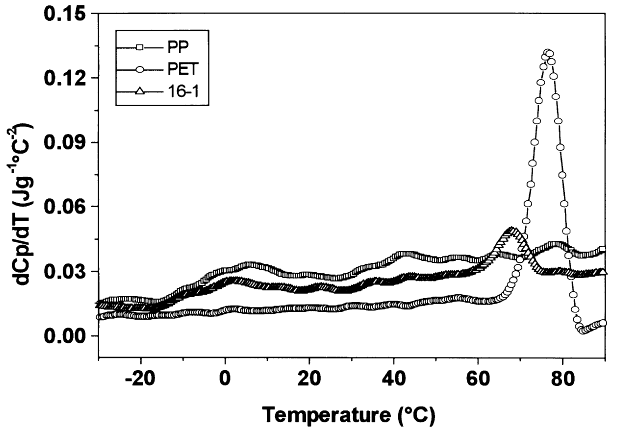


Fig. 5. Differential of heat capacity vs. temperature signals for PP, PET and the blend.

Xanthos et al. [9] reported that the T_c of a PET component was dependent on the composition of the PP/PET blends. They found that the unmodified PP/PET had the highest T_c, compared with the PP grafted with AA (6%) and PET blends (PP-g-AA/PET). In our experiments, however, the uncompatibilized PP/PET blend gave the lowest T_c, relative to the compatibilized systems. This variation might arise from the difference of composition between the two experiments. There was only 5 wt.% compatibilizer in our samples, while they used the neat PP-g-AA to blend with PET. In our experiments, the somewhat higher T_c of the compatibilized systems may result from the enhanced interaction between the two phases. The latter reduces the nucleating effect of the PP component on PET crystallization because of the occurrence of an interfacial layer.

In addition to T_m, T_c, and ΔH_c, other important and useful information obtained from M-TDSC measurements is the variation of heat capacity with temperature. In M-TDSC thermograms (Fig. 5), when the differential curve of heat capacity versus temperature is plotted, the glass transition process is displayed as a peak, not a step change as in a conventional DSC curve of heat flow versus temperature. This unique feature makes it possible to determine precisely the increment of heat capacity (ΔC_p), the T_g, as well as the onset and completion temperatures of a glass transition process [18]. Here, ΔC_p is the peak area of the glass transition, and can be calculated from the following integration.

$$\Delta C_p = \int_{T_1}^{T_2} (\mathrm{d}C_p/\mathrm{d}T)\,\mathrm{d}T = \int_{T_1}^{T_2} \mathrm{d}C_p \qquad (1)$$

where T_1 and T_2 are the onset and completion glass transition temperatures, respectively. The detailed theoretical background and mathematical treatment of the method will not be discussed here. Anyone interested can refer to a series of papers on M-TDSC published by Hourston et al. [13,14,18].

It is well known that C_p is a characteristic constant of

Table 3
M-TDSC data for the PET component in the PP/PET blends

Sample	Compatibilizer	T_g (°C)	ΔC_p (J/g/°C)	T_c (°C)	ΔH_c (J/g)	T_m (°C)
PET	—	77	0.35	125	7.5[a]	257
12-4	—	68	0.33	101	5.8	254
14-1	C-3	67	0.33	107	6.9	256
16-1	C-4	68	0.24	108	6.7	249
18-2	C-2A	67	0.29	106	6.0	253
18-4	C-2A/2402	66	0.18	107	2.7	250

[a] $0.2 \times \Delta H_c$ determined with neat PET.

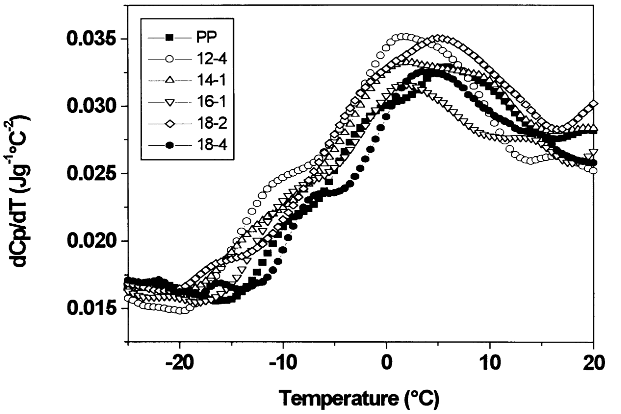


Fig. 6. dC_p/dT versus temperature signals for the PP components in the blends.

matter at a given temperature and pressure. The change of C_p at the glass transition, ΔC_p, is also a specific constant for a pure material, whether it is in the bulk state or dispersed in a medium. The importance of this characteristic lies in that it, together with the precise determination of ΔC_p, provides the basis of a method to investigate interfacial features of immiscible polymer blends. That is, for a fully phase-separated blend, the ΔC_p value of one component must be exactly the product of that in its pure state multiplied by its weight fraction in the blend, i.e.

$$\Delta C_p = \omega \Delta C_p^0$$

where ΔC_p and ΔC_p^0 are heat capacity increments in the blend and pure state, respectively and ω is the weight fraction of component i in the blend.

However, for a compatibilized blend, ΔC_p may be less than the product of $\omega \Delta C_p^0$. The loss of ΔC_p, or the difference ($\delta \Delta C_p$) between $\omega \Delta C_p^0$ and ΔC_p means a reduction of the net amount of the component in the blend, i.e. some of the component is not in the equivalent phase. This “lost” portion, mixed with other components, forms interfaces in the compatibilized blend. Thus, the $\delta \Delta C_p$ is an indication of any increase in interfacial content and can be used as a measure of compatibility for a multi-component blend [12,18]. That is

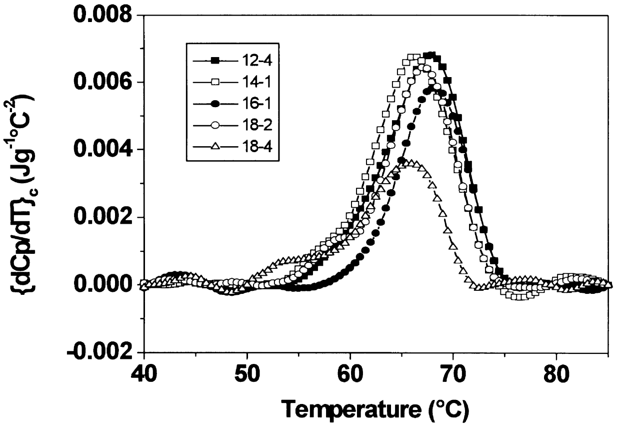


Fig. 7. Corrected dC_p/dT versus temperatures signals for the PET components in the blends.

if $\delta \Delta C_p$ is equal to zero, the blend is fully incompatible (immiscible);
if $\delta \Delta C_p$ is equal to ωC_p^0, the blend is fully compatible (miscible);
if $\delta \Delta C_p$ is between zero and $\omega \Delta C_p$, the blend is partially compatible (immiscible).

In addition to being merely a qualitative description, $\delta \Delta C_p$ can also be applied as a quantitative estimation of the extent of compatibilization as it is directly related to interface content of the blend.

In this study, M-TDSC was used to estimate the compatibilizing effectiveness of the different compatibilizers for the PP/PET blends. Fig. 6 shows the differential of heat capacity (dC_p/dT) versus temperature signals at the glass transition for the amorphous PP. The integrations for the blends minus that for PP have been chosen as a measure of the amount of amorphous PP in these blends. The calculated values were listed in Table 2. With adding compatibilizers, the fraction of amorphous PP decreases in these blends. However, these changes are irregular, as shown in Table 2. This may result from the high degree of crystallinity and the rapidity of crystallization of the PP component in the blends because crystallization affects the relative amount of amorphous PP.

Fig. 7 displays the corrected dC_p/dT versus temperature signals, $\{dC_p/dT\}_c$, for the amorphous PET phase. Here, $\{dC_p/dT\}_c = dC_p/dT - \textit{the baseline}$ where the dC_p/dT versus temperature signal generated by the PP component was considered as the baseline. For the PET component, ΔC_p data (Table 3 after being divided by their weight fractions and for $\omega = 0.2$) show a very regular variation with compatibilization. Obviously, ΔC_p becomes smaller after compatibilization, compared with the uncompatibilized blend, and its magnitude is strongly dependent upon the compatibilizers used. Sample 14-1 shows a ΔC_p value of 0.33 which is the same as that for the uncompatibilized sample 12-4, implying that compatibilizer C-3 has little compatibilizing effect on the blend. The ΔC_p values of other samples were lower than that for sample 12-4. Particularly for blend 18-4, the ΔC_p value is only half of that of neat PET. This means that a portion of PET forms interfaces with a portion of PP. In addition, this result confirms that the very low ΔH_c of sample 18-4 results from the reduction of the amount of PET bulk phase, rather than any decrease in its crystallinity. The causes for the difference in ΔC_p values originate from the different degrees of effectiveness of the compatibilizers and already have been discussed in the morphology section. It should be noticed that the trend of the ΔC_p variation with compatibilization is in very good agreement with morphologies of the blends: a larger PET domain size gives a larger ΔC_p value, and vice versa. As

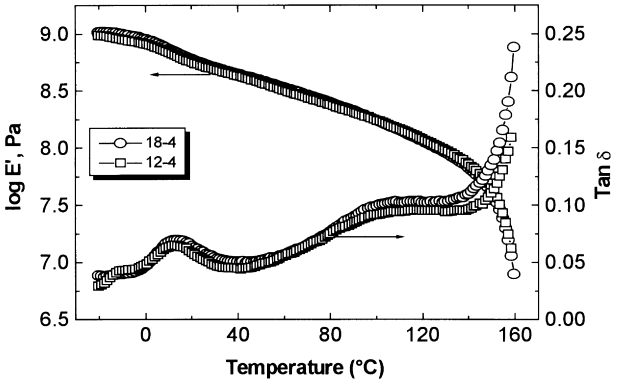


Fig. 8. DMTA results for the compatibilized and uncompatibilized PP/PET blends obtained in the bending mode.

discussed earlier, a larger ΔC_p means a lower $\delta\Delta C_p$, and hence a lower interface content.

From the aforementioned discussion, it is clear that the relation of ΔC_p values to domain sizes of dispersed phases confirms that ΔC_p is a very useful parameter to describe the compatibility of multi-component blends. Further, the magnitude of $\delta\Delta C_p$ provides a quantitative measure of the extent of compatibilization for a multi-component blend.

Fig. 8 shows the DMTA results for the compatibilized and uncompatibilized PP/PET blends. It can be clearly seen that there are no significant differences between the two samples for both the $\log E'$-temperature and the tan δ-temperature curves. That is, DMTA is not sensitive to compatibilization at this level.

3.4. Mechanical properties

Generally, the mechanical properties of immiscible blends without compatibilization are poor because of the weak interfacial adhesion between the components. Addition of compatibilizers will improve the properties if they adhere well to both immiscible components [6,19]. For uncompatibilized PP/PET blends, the mechanical properties are usually worse than the arithmetic averages of the two component polymers [8]. By using PP grafted with methyl methacrylate (0.95) and ethyl acrylate (0.05), Ilenda et al. [20] demonstrated improvements of tensile strength for PP/PET blends with composition ratios from 70/30 to 20/80. Xanthos et al. [[9]] reported that the tensile strength of the PP/PET blend compounded by reactive extrusion was increased from 34.4 to 39.9 MPa by replacement of PP with PP-g-AA. Similar results were obtained in our experiments. As shown in Table 4, the mechanical properties of PP/PET blends were improved as a result of addition of compatibilizers. The blends have higher flexural strength than neat PP because PET possesses higher stiffness and modulus. Good compatibilization (say blend 16-1) improves the property further. The slightly lower flexural strength of sample 18-4 may be caused by the reduction in the amount of the bulk PET phase as indicated by its low ΔC_p value. For tensile and impact strengths, the relatively more compatible samples 16-1 and 18-4 give obviously higher values than the others. However, the importance of mechanical data lies in the fact that their variation, particularly tensile and impact strengths, with different compatibilizers displays a similar profile to the morphologies and ΔC_p values discussed earlier. That is, a finer dispersed morphology, or a lower ΔC_p value, leads to better mechanical properties. This is as a result of the increased interface content, and, hence, strengthened adhesion between the two phases.

4. Conclusions

The compatibilizing effects of the three MAH grafted PPs for PP/PET blends depend upon their functional groups. SEM-observed morphologies show that C-4 is the most effective one among them as it produced the finest PET domain size. Substitution of 40 wt.% C-2A with a *tert*-butyl phenolic resin promotes further compatibilization. It is believed that these compatibilizing effects may result from the enhanced interaction between the two phases, owing to the introduction of polar functional groups carried by the compatibilizers.

M-TDSC measurements revealed that the T_g, T_c, T_m, ΔC_p, and ΔH_c of the PET component in the blends were all to some extent lower than those in neat PET. However, only T_c, T_m, and ΔC_p displayed obvious differences before and after compatibilization. The movement of T_c to higher temperatures by compatibilization is evidence of enhanced interfacial interaction. In addition, the change of T_m with

Table 4
Mechanical properties of the PP/PET blends. (Samples are the same as in Table 2)

Sample	Compatibilizer	Strength		
		Tensile (MPa)	Impact (kJ/m^2)	Flexural (MPa)
PP	—	32.4	5.1	68.7
12-4	—	30.9	6.3	72.8
14-1	C-3	33.2	5.9	73.4
16-1	C-4	35.2	12.3	81.2
18-2	C-2A	34.1	8.7	82.9
18-4	C-2A/2402	37.2	10.47	76.3

compatibilization, which is related to the domain sizes, is also an indication of improvement of interfacial interaction. However, the most sensitive and important parameter to compatibilization obtained from M-TDSC measurements is found to be ΔC_p, the increment of heat capacity at the glass transition. This is because ΔC_p is directly related to the interface content of the blend. The fact that the varying tendency of ΔC_p with compatibilization is entirely consistent with those of morphology and mechanical properties provides good evidence. This result suggests that ΔC_p can be used as a quantitative measure of compatibilization.

Mechanical determinations showed the improvements in tensile, impact and flexural properties by compatibilization. These are a result of finely dispersed morphology and strengthened adhesion of interfaces.

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