

Blends of poly(ethylene terephthalate) with unmodified and maleic anhydride grafted acrylonitrile–butadiene–styrene terpolymer

Nikos K. Kalfoglou*, Dimitrios S. Skafidas and Joannis K. Kallitsis

Department of Chemistry, University of Patra, 265 00 Patra, Greece

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Tensile, dynamic mechanical, thermal properties and morphology features of poly(ethylene terephthalate) (PET) blends with the acrylonitrile–butadiene–styrene (ABS) terpolymer were examined at up to 25 wt% content of ABS. Both unmodified and maleic anhydride grafted ABS (ABS-g-MA) were used. PET/ABS blends quenched from the melt and tested shortly after, show good mechanical properties—the result of component miscibility in the melt predicted by the theory and providing temporal component adhesion in the solid state. After storage, properties deteriorate due to ABS particle debonding and a polymer alloy is obtained with poor tensile properties. This property deterioration is not observed in PET/ABS-g-MA blends due to the grafting of the modified ABS particles onto the PET matrix. These findings are supported by the optical and mainly by the scanning electron microscopy examination of cryofractured and etched blends. Copyright © 1996 Elsevier Science Ltd.

(Keywords: polymer alloys; PET/ABS blends; maleic anhydride modified ABS)

INTRODUCTION

Acrylonitrile–butadiene–styrene (ABS) terpolymers are extensively used as impact modifiers^{1,2} for thermoplastics, e.g. PVC and polycarbonate (PC). The toughening has been attributed essentially to extensive craze formation between the rubbery component and the plastic matrix leading to large energy absorption³. In the case of PC/ABS blends additional advantages are the improvement of the performance/cost ratio and the resistance imparted by ABS to environmental stress cracking of the polyester. The above binary blend attracted considerable research activity and relevant work has been summarized in recent review articles^{4,5}. Contrary to other toughened plastics, e.g. nylon/ABS, which require chemical modification of ABS to develop component adhesion^{6,7}, PC and the poly(styrene–acrylonitrile) (SAN) matrix of ABS have considerable intermolecular interaction to attain a sufficiently high level of interface bonding. Paul and coworkers^{4,8} described how in the case of a PC/SAN blend, Helfand's theory⁹ incorporating basic molecular parameters and intermolecular interaction can be applied to obtain a maximum interphase thickness and a minimum interfacial tension at an optimum AN content (25 wt%) of the SAN component. Greco in his review⁵ on thermal and mechanical properties of PC/ABS blends, concluded that changing the AN content of ABS has only marginal influence on these properties. This seems to be at variance with the implications of the work of Paul and coworkers^{4,8} and additional work is necessary in this direction. Greco and coworkers¹⁰ have recently presented a scanning

electron microscopy study of selectively etched PC/ABS blends in the complete composition range. Phase inversion occurs at about 50 wt% ABS. A patent¹¹ has also described the toughening of poly(butylene terephthalate) with the addition of ethylene–propylene–diene rubber grafted with SAN.

This work focuses on the modification of another polyester with ABS, namely poly(ethylene terephthalate) (PET). To the best of our knowledge no such work has been published. Besides the importance of mechanical property improvement and diversification (in analogy to PC/ABS blends), an additional incentive was responding to the social demand for the utilization of a recyclable engineering plastic^{12,13}.

Experiments were carried out at high PET content on melt-mixed blends. Preliminary results indicated that at low ABS content significant improvement in tensile elongation was obtained in quenched blends. Subsequently it was discovered that storage at ambient temperature led to property deterioration. Thus ABS was chemically modified by maleic anhydride grafting (ABS-g-MA), prior to mixing with PET, since it was expected that this would promote ABS attachment onto PET via the MA functionality reacting with the terminal hydroxyl⁹ of the polyester¹⁴.

EXPERIMENTAL

Materials

PET was extrusion grade obtained from Akzo Plastics b.v., (Arnite DO2 300). It was reported to have predominantly terminal hydroxyl groups, an M_n value of 23 500 g mol⁻¹, a T_m of 252°C and a density of 1.34 g cm⁻³. ABS (Magnum 3453) was extrusion grade

* To whom correspondence should be addressed

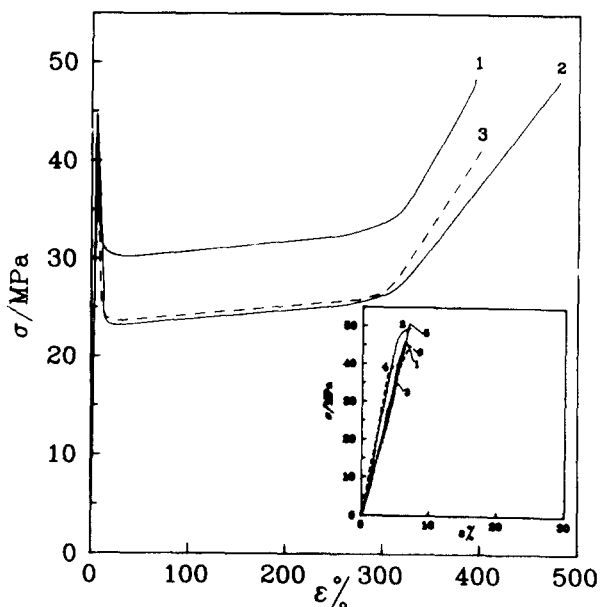


Figure 1 Stress-strain properties of PET/ABS blends: (1) 100/0; (2) 95/5; (3) 90/10. Inset: (1) 85/15; (2) 75/25; (3) 10/90; (4) 0/100; (5) 95/5(aged); (6) 90/10(aged)

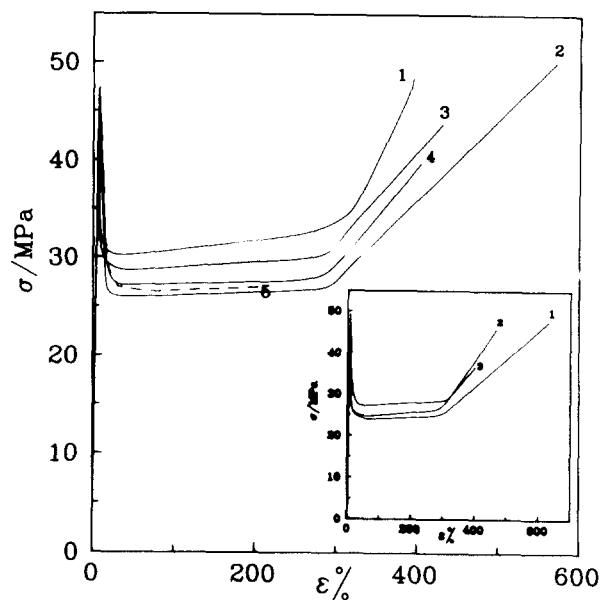


Figure 2 Stress-strain properties of PET/ABS-g-MA blends: (1) 100/0; (2) 95/5; (3) 90/10; (4) 85/15; (5) 80/20/ Inset: aged blends: (1) 95/5; (2) 90/10; (3) 85/5

Table 1 Tensile properties of PET/ABS blends^a

Composition	σ_y (MPa)	σ_b (MPa)	ϵ_b (%)	E_b (J cm ⁻³)
100/0	43 ± 1	48 ± 2	394 ± 85	134
95/5	44 ± 1	48 ± 2	479 ± 77	147
95/5(aged)	51 ± 1	48 ± 1	9 ± 1	3
90/10	43 ± 1	41 ± 1	398 ± 36	116
90/10(aged)	45 ± 1	43 ± 1	8 ± 2	2
85/15	46 ± 2	41 ± 2	7 ± 1	2
75/25	49 ± 1	49 ± 1	7 ± 1	2
10/90	35 ± 1	33 ± 1	6 ± 1	1
0/100	40 ± 1	40 ± 1	5 ± 1	1
90/10 ABS(25 AN)	44 ± 2	24 ± 3	48 ± 10	19
80/20 ABS(25 AN)	43 ± 2	42 ± 2	7 ± 1	2

^a Quenched to 0 °C

with MFI 5 g/10 min (230°C, 3.8 kg) donated by Dow Hellas Co. Spectroscopic analysis¹⁵ gave the following composition: 51.0 wt% PS, 20.4 wt% AN and 28.6 wt% PBD.

Preparation of ABS-g-MA. ABS (25 g) was dissolved in 100 ml toluene, then degassed and blanketed with inert gas. To the thermostated solution at 90°C, 2.5 g maleic anhydride (MA) followed by 0.31 g benzoyl peroxide were added with continuous stirring. The solution was stirred vigorously for 1.5 h to complete the reaction and the product precipitated with constant stirring in excess methanol, washed and finally extracted with methanol to remove unreacted MA. The product was dried overnight at 50°C in a vacuum oven and identification¹⁶ was performed using FT i.r. to determine the characteristic absorption at 1780 cm⁻¹. The amount of MA grafted was determined¹⁷ by titrating a tetrahydrofuran solution of ABS-g-MA with a 0.1 N KOH solution with phenolphthalein as an indicator. Analysis gave 3.5 wt% MA grafted for a 1.5 h reaction time and 4.6 wt% for a 4 h period. Except where noted all blends were prepared with the former product.

Apparatus and procedures

Optical micrographs were obtained with an Olympus

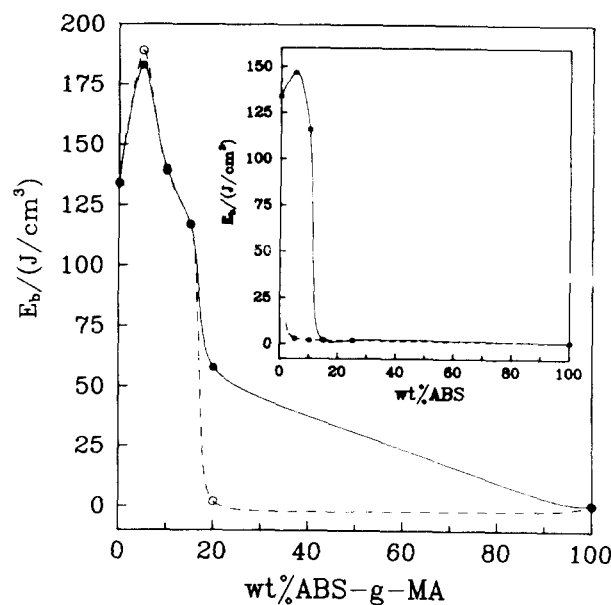


Figure 3 Composition dependence of energy to tensile failure E_b of PET/ABS-g-MA blends: (●) non aged; (○) aged. Inset: PET/ABS blends: (●) non aged; (○) aged

BH-2 microscope. Specimens were prepared by melt pressing material between the cover glass and microscope slide and quenching to 25°C. D.m.a. data complex modulus $|E^*|$ and $\tan \delta$ were determined at 110 Hz using a Rheovibron Model DDV II-C. Tensile tests were performed at a crosshead speed of 10 cm min⁻¹ and 23°C according to ASTM D 882 using a J.J. Tensile Tester type T5001 and rectangular film strips measuring 40 × 6.5 × 0.25 cm³. D.s.c. measurements were made with a DuPont 910 calorimeter coupled with a 990 programmer recorder. Nominal weight was 10 mg and the heating rate was 10°C min⁻¹ for T_g and 20°C min⁻¹ for crystallinity determination. SEM was carried out with a JEOL model JSM-5200. Surfaces cryofractured under impact, or microtomed and etched with dichloromethane

Table 2 Tensile properties of PET/ABS-g-MA blends^a

Composition	σ_y (MPa)	σ_b (MPa)	ε_b (%)	E_b (J cm ⁻³)
100/0	43 ± 1	48 ± 2	394 ± 85	134
95/5	44 ± 2	50 ± 4	566 ± 121	183
95/5 (aged)	46 ± 3	48 ± 1	633 ± 120	189
90/10	43 ± 2	44 ± 1	435 ± 47	140
90/10 (aged)	45 ± 2	46 ± 1	465 ± 39	139
85/15	48 ± 1	40 ± 2	403 ± 52	117
85/15 (aged)	49 ± 1	37 ± 3	400 ± 30	117
80/20	44 ± 1	27 ± 2	212 ± 125	58
80/20 (aged)	46 ± 1	45 ± 1	8 ± 1	2
0/100	41 ± 1	39 ± 1	10 ± 2	1
95/5 ^b	44 ± 1	46 ± 2	490 ± 105	158
90/10 ^b	43 ± 2	40 ± 2	415 ± 117	111

^a Quenched to 0°C, with a 3.5 wt% MA^b With 4.6 wt% MA**Table 3** Effect of thermal treatment on tensile properties of PET/ABS-g-MA blends

Composition	σ_y (MPa)	σ_b (MPa)	ε_b (%)	E_b (J cm ⁻³)
Annealing at 80°C for 2 h				
100/0	48 ± 1	54 ± 2	570 ± 120	179
95/5	46 ± 2	24 ± 2	43 ± 9	15
90/10	51 ± 2	27 ± 1	21 ± 2	6
85/15	46 ± 1	43 ± 2	10 ± 1	3
80/20	48 ± 1	46 ± 3	8 ± 3	2
Annealing at 140°C for 2 h				
100/0	73 ± 2	70 ± 3	8 ± 2	4
95/5	62 ± 3	57 ± 4	12 ± 3	5
90/10	63 ± 3	59 ± 1	11 ± 1	4
85/15	59 ± 1	57 ± 3	9 ± 1	3
80/20	61 ± 1	57 ± 4	9 ± 3	4

were examined at a tilt angle of 30°. FTi.r. spectra were obtained using a Perkin-Elmer 1600 spectrometer.

PET was dried in a vacuum oven at 150°C for 12 h, ABS at 60°C for 10 h. Two series of blends were prepared: PET melt-blended with unmodified ABS at 280°C using a CSI Max Mixing Extruder, Model CS-194 AV at 45 rpm. Compositions were 95/5, 90/10, 87.5/12.5, 85/15, 75/25 the first numerical denoting PET. The other series of blends contained ABS-g-MA with compositions 95/5, 90/10, 85/15, 80/20 with an MA content of 3.5 wt%. Both types of blends were studied before and after storage for a period of 7 days at ambient temperatures. To determine the influence of AN content in ABS, a poly(styrene-co-acrylonitrile) (SAN) having 30 wt% AN was melt-mixed with ABS so as to increase its AN content to 25 wt%. Two blends 90/10 (AN 25) and 80/20 (AN 25) were prepared. To provide adequate reaction time, blends with ABS-g-MA were prepared in a small glass reactor at 280°C under inert gas with mechanical stirring. Mixing time was 12 min. Films for testing were prepared by compression moulding between Teflon sheets at 275°C and 50 kg cm⁻² followed by pressure release and quench to 0°C. Melt-pressed films were examined with FTi.r. soon after preparation and after storage for one month.

RESULTS

Tensile properties

PET/ABS blends. The results are summarized in Figure 1 in terms of stress-strain σ - ε % curves and in

Table 1 where the ultimate properties σ_b and ε_b , the energy to tensile failure E_b obtained as the area under the σ - ε curves and σ_y the yield stress are tabulated. These curves represent the 'average' of 5-8 tests. These data indicate good tensile and ultimate properties at low ABS contents (< 10 wt%). Elongation at break ε_b , a sensitive indicator of phase adhesion in polymer alloys as well as E_b see Figure 3 (inset) and Table 1, are drastically reduced at higher ABS contents as well as during storage at ambient temperature after a period of 7 days. Some clues as to the origin of this 'physical' ageing will be presented below. Table 1 also shows that increasing the AN content in ABS does not improve tensile properties in agreement with the findings of Greco⁵.

PET/ABS-g-MA. Grafting ABS onto the PET matrix drastically improves ultimate properties (see Table 2 and Figures 2 and 3). It is noteworthy that the 95/5 and 90/10 compositions have higher E_b values compared to PET. What is most important is that after storage at room temperature properties at the compositions of interest are maintained. Table 2 indicates also that using modified ABS with a higher MA content reduces somewhat the E_b values apparently the result of a higher degree of crosslinking reducing material ductility. Tests were also performed on PET/ABS-g-MA blends after thermal treatment at elevated temperatures to accelerate PET crystallization (see Table 3). The results indicate a significant drop of ε_b and E_b caused by PET crystallization affecting the matrix/filler bonding (at 80°C) and the PET matrix embrittlement (at 140°C).

Dynamic mechanical properties

PET/ABS blends. The results are given in Figures 4 and 5 in terms of the temperature dependence of the storage E' and loss modulus E'' at various compositions. Below T_g both pure components have comparable E' values. However increase of the ABS content leads to

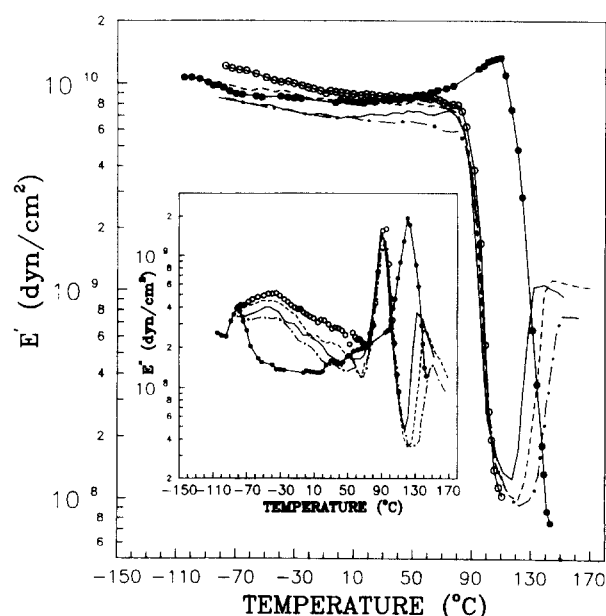


Figure 4 Temperature dependence of storage modulus of PET/ABS blends: (○) 100/0; (- - -) 95/5; (—) 90/10; (· · ·) 85/15; (●) 0/100. Inset: loss modulus at corresponding compositions

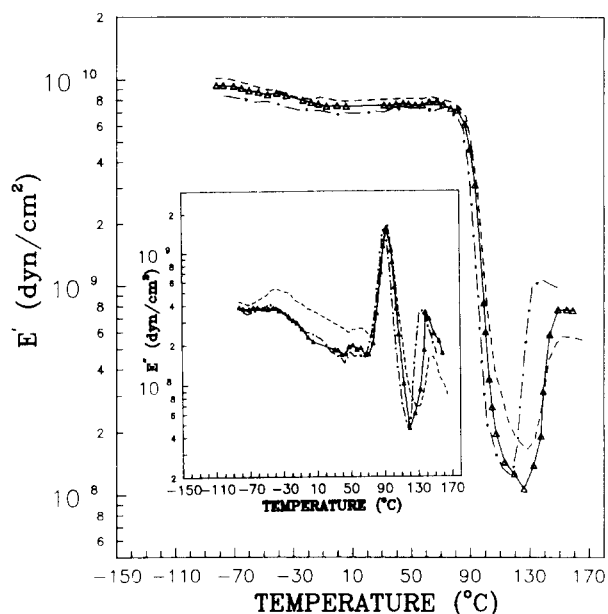


Figure 5 Temperature dependence of storage modulus of PET/ABS blends: (Δ) 75/25; (---) 90/10 (non aged); (- - -) 90/10 (aged)

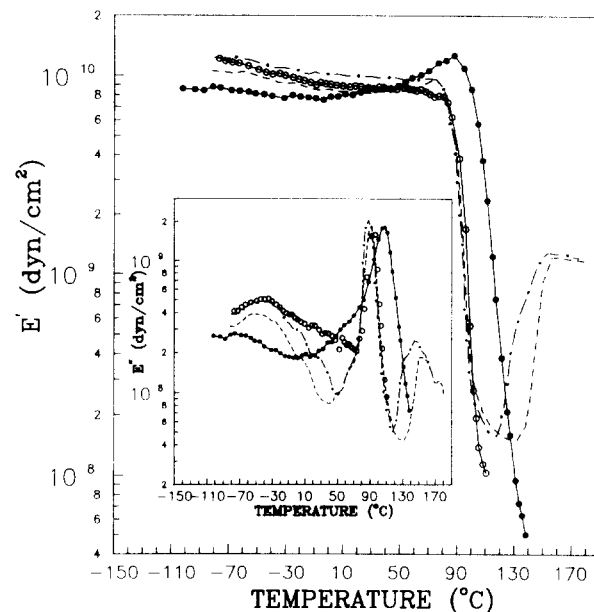


Figure 6 Temperature dependence of storage modulus of PET/ABS-g-MA blends: (\circ) 100/0; (---) 95/5; (- - -) 90/10; (\bullet) 0/100. Inset: loss modulus at corresponding compositions

Table 4 Viscoelastic and thermal properties of blends^a

Composition	Temperatures of main relaxations (°C) ^b					
	PET		ABS		T_m (°C)	Crystallinity ^c
	α	β	α	β	PET	Blend
PET/ABS blends						
100/0	93	-37	-	-	255	20.6
95/5	89	-36	-	-	252	25.9
90/10	90	-44	-	-	251	26.0
87.5/12.5	-	-	-	-	251	26.9
85/15	93	-38	-	-	251	28.6
75/25	94	-37	-	-	254	33.6
0/100	-	-	121	-82	-	-
PET/ABS-g-MA blends						
100/0	93	-37	-	-	255	20.6
95/5	87	-37	-	-	246	30.2
90/10	90	-46	-	-	243	29.7
85/15	91	-43	-	-	245	29.0
80/20	89	-30	-	-	245	28.5
0/100	-	-	108	-78	-	35.6

^a Quenched films

^b E'' maxima

^c Bulk crystallinity

^d $\Delta H_f = 33.5 \text{ cal g}^{-1}$

modulus reduction below that of ABS at up to about 15 wt% ABS. This may be attributed to stresses developed in the solid¹⁸ because of differing expansivity of the matrix and the ABS particles. Further addition of ABS (25 wt%) reverses the trend; however at these compositions a morphology change (spheres to interpenetrating domains) takes place (see section on morphology). Both components show prominent sub- T_g secondary relaxations; ABS at about -82°C due to PBD and PET at about -37°C . While the β -PET relaxation persists in all blends with some shift to lower temperatures, and diminishing in strength, see Table 4, the β -ABS relaxation disappears. It is not clear whether this is due to dilution or is the effect of thermal shrinkage stresses. At higher ABS contents (>15 wt%) the sub- T_g relaxation increases again. Other main relaxations are tabulated in Table 4. Of interest is

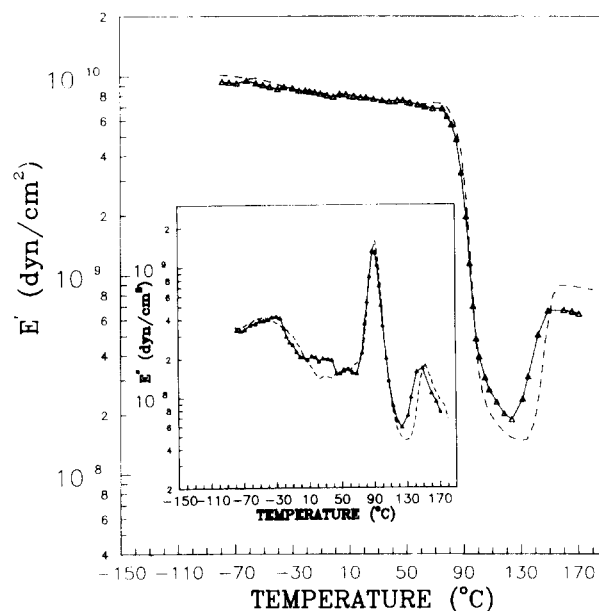


Figure 7 Temperature dependence of storage modulus of PET/ABS-g-MA blends: (- - -) 85/15; (Δ) 80/20

the disappearance of the main ABS relaxation at 121°C even at high contents. The modulus 'hump' beyond the 130°C is due to the recrystallization of PET during the thermal scan and has been reported before¹⁹. The effect of storage on d.m.a. properties are shown in Figure 5. The aged 90/10 blend shows some modulus increase below T_g . This is expected if during storage particle debonding takes place leading to stress relief.

PET/ABS-g-MA blends. In these blends, E' values below T_g are intermediate between those of pure components. This supports the absence of shrinkage stresses (see Figures 6 and 7). Relaxation spectra show a shift of the PBD peak to higher temperatures caused by grafting with the bulky MA moiety and a concomitant reduction

of its main relaxation (T_g) from 121 to 108°C. This may be attributed to a free volume increase and/or the weakening of the polar forces due to the CN of ABS. The β -relaxation area in blends when prepared under similar conditions is expected to be related to impact properties²⁰ or approximately in this case to E_b . Figure 8 shows such a correlation between E_b and area or alternatively E_b and blend composition. Best properties are obtained at about 5 wt% ABS-g-MA.

Thermal properties

These are summarized in Table 4. A small $T_{m,PET}$ reduction in blends could be attributed to crystal size reduction. It is more pronounced in PET/ABS-g-MA blends. It is also seen that crystallization of PET during the thermal scan is facilitated by the presence of ABS in both blend series, the additive acting presumably as a nucleating agent. T_g values determined with d.s.c. are systematically lower (frequency effect) and less accurate because of the proximity of main component transitions.

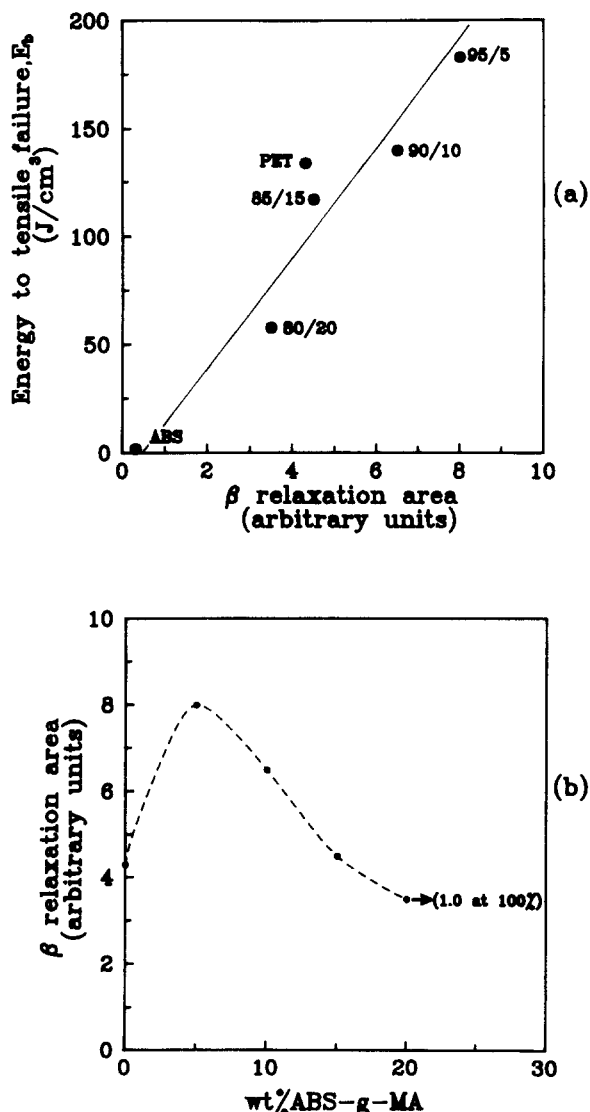


Figure 8 (a) Correlation of energy to tensile failure of PET/ABS-g-MA blends with β relaxation area. (b) Composition dependence of β relaxation area

FTi.r. spectroscopy

No changes in the FTi.r. spectra of as prepared films and after storage at ambient conditions were detected. Thus no chemical structure changes are to be associated with the physical changes observed in the non-grafted blends.

Morphology

Optical microscopy. Given the composite structure of ABS its phase-contrast micrograph would show dark and light areas corresponding to SAN and PBD, respectively²¹. Similar features are evident in PET/ABS blends (Figure 2a-d) where PET constitutes the dark background. At higher ABS contents (≥ 15 wt%) the spherical isolated ABS domains deform and the onset of an interpenetrating phase morphology is discernible. Grafting causes spreading of the ABS droplets—the result of surface tension reduction due to chemical reaction at the interface during melt mixing (see Figures 9e-h). Micrographs of quenched blends with crossed polars not included in this report, show amorphous blends except for the PET/ABS 90/10 composition where some crystallite submicron domains are evident. This is more clearly seen in the 90/10 aged blend. This is to be expected since ABS debonding may facilitate PET crystallization. No essential differentiation was detected when compared with PET/ABS-g-MA blends.

Scanning electron microscopy. Examination of cryo-fractured surfaces of PET/ABS blends in Figure 10 reveals considerable matrix shear yielding at low ABS contents. Selective etching with dichloromethane to remove ABS reveals an interpenetrating network at above 15 wt% ABS (Figure 10e). Cryofractured surfaces of PET/ABS-g-MA blends, Figure 11, reveal submicron ABS particles firmly attached into the PET matrix whose ridged texture reveals shear yielding. In Figure 12, etched blends show a radically different morphology compared to PET/ABS blends where the non-grafted minor component could be easily removed from the matrix; compare with Figures 10c-e.

DISCUSSION

To explain the properties of PET/ABS blends, before storage at ambient temperature, one should consider the possibility that some interaction may exist between the SAN component of ABS and PET in analogy to other SAN/polyester blends^{4,8}. Calculation of the solubility parameter δ of the two components over an extended temperature range shows that at high temperatures they converge intersecting near the T_m of PET (see Figure 13). Use was made of the relationship²² $\partial \ln \delta / \partial T = -\alpha$ relating δ to the coefficient of thermal expansion, α . This suggests some degree of component miscibility most probably confined at the interface since ABS is cross-linked. Another instructive way is to examine the effect of composition at various temperatures, by calculating the Gibbs free energy of mixing, ΔG_m , using the following expression²³:

$$\Delta G_m/V = (RT/V_r)[(\phi_1/x_1) \ln \phi_1 + (\phi_2/x_2) \ln \phi_2 + \chi_{12}\phi_1\phi_2] \quad (1)$$

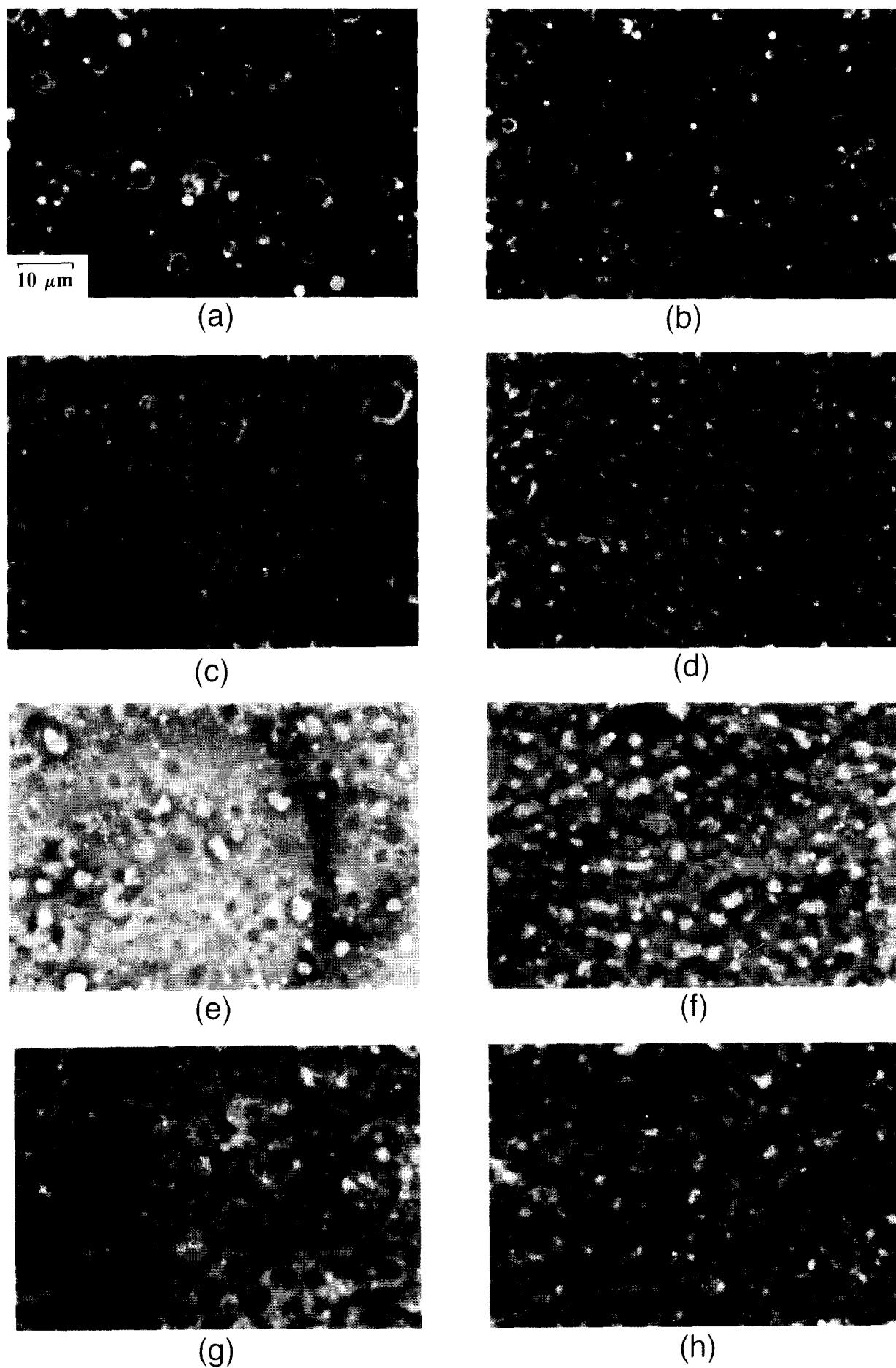


Figure 9 Phase contrast micrographs of PET/ABS blends: (a) 95/5; (b) 90/10; (c) 85/15; (d) 75/25. PET/ABS-g-MA blends: (e) 95/5; (f) 90/10; (g) 85/15; (h) 80/20

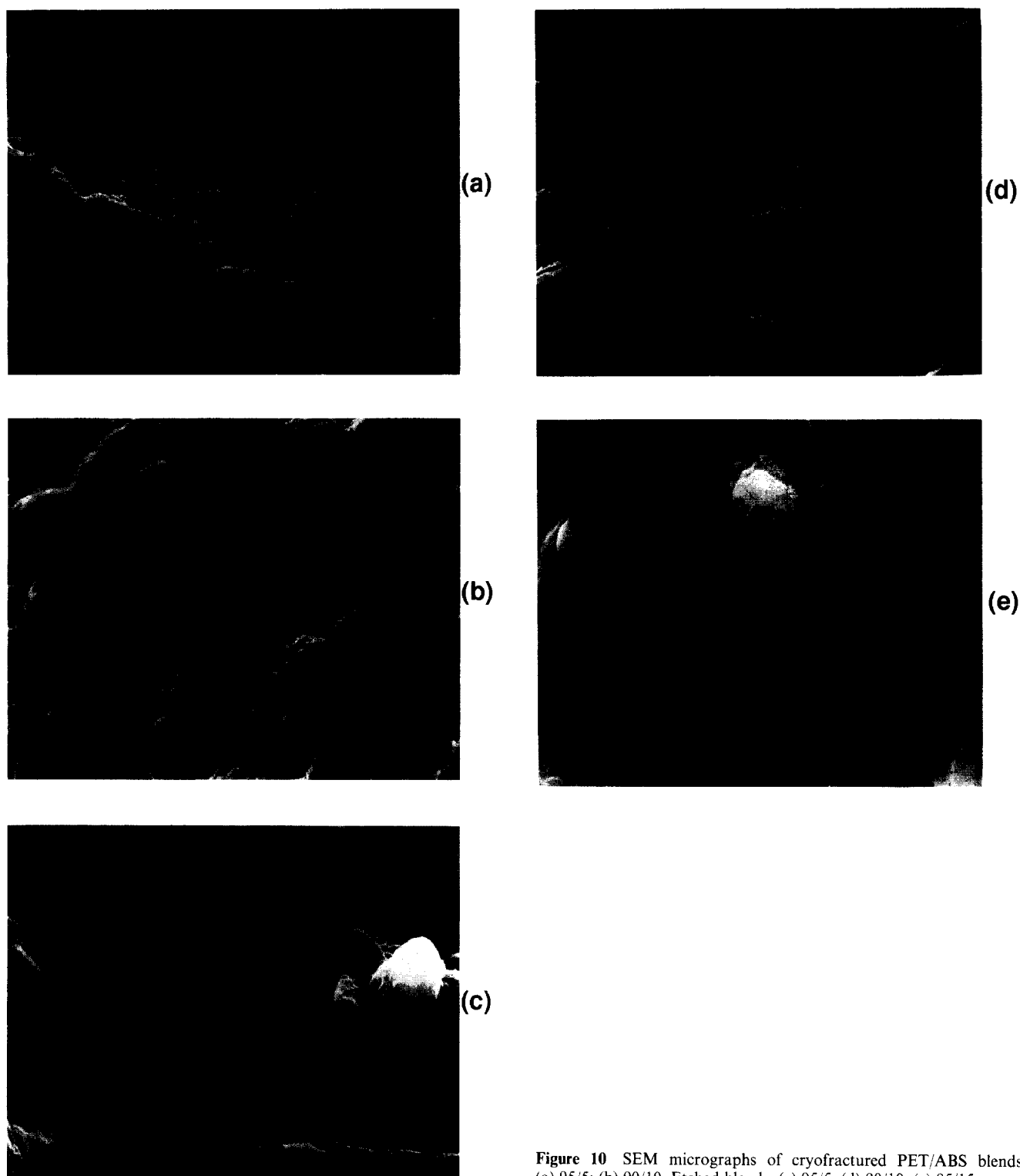


Figure 10 SEM micrographs of cryofractured PET/ABS blends: (a) 95/5; (b) 90/10. Etched blends: (c) 95/5; (d) 90/10; (e) 85/15

where V is the blend volume; V_r is the molar volume of the smallest repeat unit; χ_{12} the Flory–Huggins interaction parameter; ϕ_i is the volume fraction of polymer i and x_i its degree of polymerization in terms of V_r . The quantity χ_{12} was calculated from the previously determined δ values and the expression²⁴:

$$\chi_{12} = (V_r/RT)(\delta_1 - \delta_2)^2 \quad (2)$$

The results are shown in *Figure 14* at various temperatures. MW of ABS was varied up to very high values (crosslinked structure) but this did not significantly affect results. Inspection of *Figure 14* shows a zero value

for $\Delta G_m/V$ at about 280°C at all compositions and positive values (instability) at ambient and $T > 280^\circ\text{C}$ temperatures. It is also indicated that intermediate compositions are more unstable. Calculations were also made with the experimentally determined interaction parameter $\chi_{12} = 0.034$ at 140°C of the analogous blend PC/ABS reported by Kim and Burns²⁵. The $\Delta G_m/V$ obtained at this temperature is positive and smaller compared to that obtained for the present system (0.0085 versus 0.0434 cal cm⁻³); hence one would expect a higher degree of compatibility for the PC/ABS blend. Indeed a $T_{g,PC}$ shift with blend composition was



(a)



(b)



(c)

Figure 11 SEM micrographs of cryofractured PET/ABS-g-MA blends: (a) 95/5; (b) 90/10; (c) 85/15

observed²⁵. It should be noted that other parameters as well determine the state of mixing in the melt, e.g. viscosity ratio of components (PET having a lower viscosity than ABS) and the crosslinked structure of ABS thus obtaining a dispersion of ABS droplets in the PET matrix.

Though thermodynamic considerations predict miscibility this in reality is confined at the interface. Grafting PET at elevated temperatures with ABS-g-MA, stabilizes morphology and hinders particle debonding as SEM



(a)



(b)



(c)

Figure 12 SEM micrographs of etched PET/ABS-g-MA blends: (a) 95/5; (b) 90/10; (c) 85/15

morphology examination shows, thus maintaining good mechanical properties. At higher ABS contents (>25 wt% $\cong \phi_{\text{ABS}} = 0.30$) particle agglomeration²⁶ may lead to poor adhesion thus reducing tensile properties. At the other end of composition the high ABS content reduces blend ductility.

Values adopted in previous calculations were: $\rho(\text{amorphous PET}) = 1.34 \text{ g cm}^{-3}$; $\rho(\text{ABS}) = 1.063 \text{ g cm}^{-3}$ (calculated as the volume average from its constituents). Coefficient of specific expansivity²⁷:

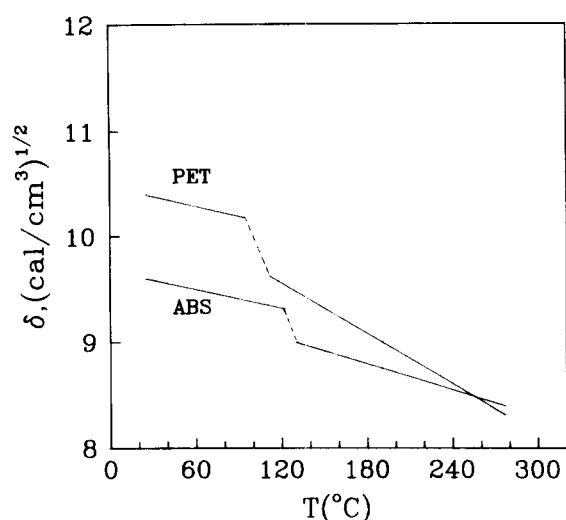


Figure 13 Temperature dependence of δ of pure components

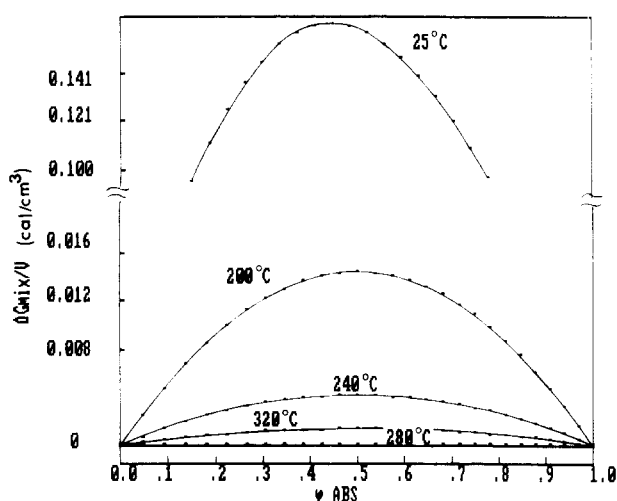


Figure 14 Composition dependence of the free energy of mixing for PET/ABS blends at various temperatures

$e_g(\text{PET}) = 2.3 \times 10^{-4} \text{ cm}^3 \text{ g}^{-1} \text{ K}^{-1}$, $e_l(\text{PET}) = 6.7 \times 10^{-4} \text{ cm}^3 \text{ g}^{-1} \text{ K}^{-1}$. For ABS given²⁸ the linear coefficient of expansion, β , since²⁷ $\alpha = 3\beta = \rho e$

$$\alpha_g(\text{ABS}) = 3 \times 10^{-4} \text{ K}^{-1} \quad \text{and} \quad \alpha_l = 5.92 \times 10^{-4} \text{ K}^{-1}$$

using the Simha-Boyer relationship $(\alpha_l - \alpha_g)T_g = 0.115$ for $T_g = 394 \text{ K}$: $\delta_{\text{PET}} = 10.4 \text{ cal}^{1/2} \text{ cm}^{-3/2}$ (at 25°C)²⁹, $\delta_{\text{ABS}} = 9.6 \text{ cal}^{1/2} \text{ cm}^{-3/2}$ (at 25°C) (calculated as the volume average from its constituents). The molar volumes²⁷ $V_{\text{PET}} = 144.5 \text{ cm}^3 \text{ mol}^{-1}$ and V_{ABS} (nominal) = $77.8 \text{ cm}^3 \text{ mol}^{-1}$ taken as V_r (calculated as the volume average from its constituents).

CONCLUSIONS

1. PET/ABS blends quenched from melt have good tensile properties at low ABS content, which deteriorate during storage at room temperature.
2. At elevated melt temperatures miscibility at the

component interface is predicted. However at ambient temperature phase separation predicted by solubility parameter theory and the mismatch of component expansivity lead to poor adhesion and particle debonding during storage. Thus mechanical properties deteriorate.

3. Grafting of ABS-g-MA onto PET stabilizes morphology and mechanical properties due to the anchoring of ABS-g-MA onto the matrix, the optimum content of modified ABS being about 5 wt%.

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