JOURNAL OF MATERIALS SCIENCE **28** (1993) 4119–4128

A study on compatibilization of AES/PA6 blends

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Polyblends of Nylon 6 and AES were prepared and their mechanical properties and phase morphology examined. Two compatibilization techniques were evaluated: addition of a suitable block copolymer: poly(styrene-co-maleic anhydride) (SMA); AES functionalization with maleic anhydride (MA) through reactive extrusion. As a preliminary test for the compatibilizing efficiency, SMAs and PA6 were compounded in a Brabender mixer, recording the torque during the operations and evaluating, by solvent extraction, the amount of SMA grafted to PA6. However, when moving to the ternary blends AES/SMA/PA6, the highest value of notched Izod impact strength (290 J m^{-1} versus 20 J m^{-1}) was found for an SMA sample containing 24% MA, which did not show the highest reactivity with PA6 in the preliminary test run. This finding suggests that not only the reactivity towards PA6, but also the miscibility with AES phase (the highest for the SMA product with 24% MA) must be taken into account when designing the best performing compatibilizer. On the other hand, AES functionalization with MA and DCP proved to be more successful and the resulting 50/50 blend with PA6 exhibited an outstanding value of notched Izod impact strength (1050 J m^{-1})

1. Introduction

The study of polymer blends and alloys is a subject of considerable interest. Much research has been focused on the preparation of miscible polymer blends, i.e. those where a single phase on a molecular scale is afforded. Several hundreds of polymers miscible either in all proportions or over limited composition ranges have been discovered [1–4]. However, very few of them have reached commercial production, the most important one being the high impact polystyrene poly(2,6-dimethyl 1,4 phenylene-ether) (PPE) [5–8].

However, it is not difficult to achieve a polymer blend consisting of two or more phases, with an interfacial energy sufficiently low and, as a consequence of that, with a good combination of physical and mechanical properties. The term "compatible" is often used for such systems and the majority of commercial blends belongs to this type, e.g. poly-(carbonate)/poly(acrylonitrile-co-styrene-g-butadiene) (ABS) [9–13] or high impact poly(butylene terephtalate) [14, 15]. In other cases, the polymer components must be "compatibilized" by the addition of appropriate block or graft copolymers that act as interfacial agents [16–26]. High-impact polystyrene/polyethylene blends can be considered as an example [27, 28]. It is also possible to form *in situ* during blend preparation, the block or graft copolymer needed, by reacting the pre-functionalized polymeric components [29–32].

Sometimes, even if properly compatibilized, a polymer blend needs a further component, usually an impact modifier, in order to display good mechanical properties. PPE and polycaprolactam (PA6) blend is a remarkable example: first, MA is used as a compatibilizing agent, then a suitable impact modifier is added [33–35]. This rubbery polymer must also have a proper structure, e.g. diblock or triblock copolymer; in order to prevent thermal degradation, hydrogenated rubbers are suggested for PPE/PA6 blends. The above mentioned blend is now stimulating a remarkable interest in the market.

The blend of PA6 (expensive, brittle but with good chemical resistance) and ABS (cheaper, very tough) also affords a commercially appealing product, with a good cost–performance balance; this blend, like the former one, needs a proper compatibilizer between the two glassy matrices.

On examining PA6, it appears an interesting polymer for reactive coupling, owing to the presence of the basic (amine) and acidic (carboxyl) end groups. In their exhaustive study, Triacca *et al.* (36) have reported that PA6 and ABS can be properly compatibilized by adding a suitable copolymer, such as poly(styrene-co-maleic anhydride) (SMA), miscible with the SAN phase but also capable of reacting with the Nylon 6 to form *in situ* a graft copolymer, by means of its MA functional groups. According to Lavengood *et al.* [37] PA6 and ABS can also be compatibilized by a terpolymer containing styrene, acrylonitrile and a low amount of MA (0.05%–4%): the resulting blend exhibits high notched Izod impact strength (850 J m^{-1}). As far as the impact properties are concerned, as is well known for PA6s, a sharp tough–brittle transition occurs at a critical particle size, when the rubber content and the rubber–matrix adhesion are constant [38–41]. The general criterion for toughening PA6 is that the interparticle distance, *ID*, must be smaller

TABLE I SMA copolymers

		SMA1	SMA2	SMA3
Maleic anhydride (%)		10.2	50	23.9
Molecular weight		200 000	100 000	180 000
Vicat 5 kg (°C)	(ISO 306)	114	-	136
MFI (220 °C/10 kg)	(g/10 min, ASTM D 1238)	36	-	11

than the critical value ID_c (0.304 μm at 23 °C) and this point should be kept in mind in optimizing any blend formulation of this kind.

In our Research Centre we have studied the synthesis of the mass-polymerized poly(acrylonitrile-co-styrene-g-EPDM) (AES) in a pilot plant and then in an industrial plant [42]. Yield and impact strengths in AES polymers have been extensively investigated by Cigna *et al.* [43], taking into account the fracture mechanics behaviour of the matrix, with the rubber particles as stress-intensification sites. As is well known, AES exhibits outstanding Izod impact strength (over 800 J m^{-1} with 30% EPDM rubber) and good weather resistance; also, the morphology of the rubbery phase appears to be very small, fit for toughening PA6-based blends. However, like ABS, AES and polyamides are incompatible, so the binary blend shows rather poor mechanical properties.

Following the "traditional" approach to the problem, we have first examined the use of a suitable compatibilizer, such as poly(styrene-co-maleic anhydride) (SMA), and in order to design the best structure for it, we first evaluated the reactivity of SMA with the PA6 during melt mixing.

The effects of different molecular weights and maleic anhydride contents of the SMA copolymer have also been explored. Ternary blends AES/PA6/SMA were then prepared and tested for mechanical properties and morphology. Then, in order to improve further the mechanical properties of the ternary blend and as an alternative to the "traditional" approach, we studied AES functionalization with MA and peroxide through reactive extrusion, which is well known to be an attractive and economically viable route for the functionalization of polyolefins with MA [44–47]. A blend of AES-g-MA/PA6 was then prepared and tested for its mechanical properties.

2. Experimental procedure

2.1. Materials

As the polyamide 6, Ternyl B 27 (Enichem Polimeri) has been used. The relative viscosity is 2.70 (1% solution in 95.6 wt% sulphuric acid, 23°C) [48]. The AES resin was a pilot plant sample, with 30% EPDM rubber (24% acrylonitrile, referred to as SAN copolymer).

Different kinds of SMA copolymer were prepared, with different levels of MA content: 10.2% (SMA1), 23.9% (SMA3) and 50% (SMA2) (see Table I for the main features). Dicumylperoxide (Akzo Chemie, Perkadox BC) was used without further purification.

2.2. Equipment

The SMA/PA6 blends were prepared in an internal mixer Brabender Plasticorder, model PLE 651, with a 300 cm^3 cell, recording the torque versus processing time at a given temperature (220 °C) and speed (60 r.p.m.).

AES/PA6/SMA blends, the functionalization of AES with MA and peroxide and AES-g-MA/PA6 blends were prepared in a Baker–Perkins twin-screw extruder, model MPC V 30. The machine features are as follows: screw diameter 30 mm, temperature range 220–250°C, screw speed 300 r.p.m., vented.

For the evaluation of notched Izod impact strength (ASTM D 256), tensile properties (ASTM D 638) and Vicat softening temperature (ASTM D 1525), test specimens were moulded using a Negri and Bossi (model V 17) injection-moulding machine, under the following conditions: injection moulding temperature 220–230 °C, mould temperature 30 °C, injection moulding pressure 10 MPa, back pressure 6.5 MPa, injection speed 70 r.p.m. Immediately following moulding, the samples were introduced into a sealed plastic bag or a desiccator to avoid moisture sorption. All these samples were tested dry, as-moulded.

2.3. Solvent extraction

PA6/SMA blend samples (about 2–3 g each), ground to a very fine form, were extracted in a Soxhlet apparatus with tetrahydrofuran (THF) and formic acid (about 150 ml for each sample).

The THF extraction (10 h at boiling temperature) affords a soluble fraction, consisting of unreacted SMA and a residue of PA6 and PA6-g-SMA.

In the second step, the above residue was extracted with formic acid at 23 °C for 5 h, and then filtered with a Gooch no. 3, separating the soluble PA6 (see Fig. 1). Each extraction was repeated several times until complete removal of the free SMA and PA6 was achieved.

In order to check the efficiency of the separation, Fourier transform–(FT–IR) infrared spectra were recorded on single fractions after precipitation in ethanol, and on the residue.

2.4. Chemical analysis

The chemical analysis of the whole MA (grafted on to AES + free) was carried out by recording FT–IR spectra on a thin film prepared by compression moulding at 220 °C (200 μm thick). In order to analyse the free MA, the AES-g-MA samples (about 5 g each), ground to a very fine form, were dissolved in chloroform and then precipitated in a 1/10 vol/vol chloroform/ethanol solution.

The free MA was evaluated on the fraction soluble in chloroform, by polarography, working at a constant pH of 8.2. Analysis of the linked MA was carried

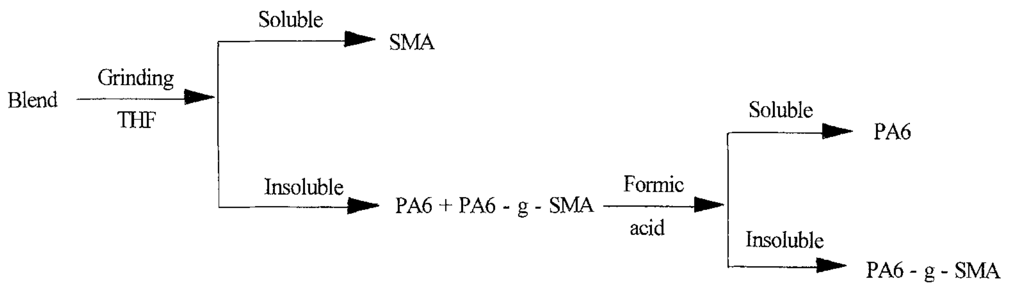

Figure 1 Phase separation scheme.

out on the precipitated fraction by recording FT–IR spectra on a thin film prepared by compression moulding at 220 °C (200 μm thick).

The precipitated fraction was suspended in methyl ethyl ketone (MEK) and centrifugated in order to separate the insoluble part (gel phase) from the soluble one (resinous phase, SAN). The resinous phase was precipitated in ethanol, dried for at least 12 h at 80 °C in a vacuum oven, to ensure a complete removal of sorbed alcohol, and compression moulded into thin films (200 μm thick).

The chemical analysis, by FT–IR spectroscopy revealed no MA in this phase (SAN); therefore, all the MA was grafted to the gel phase.

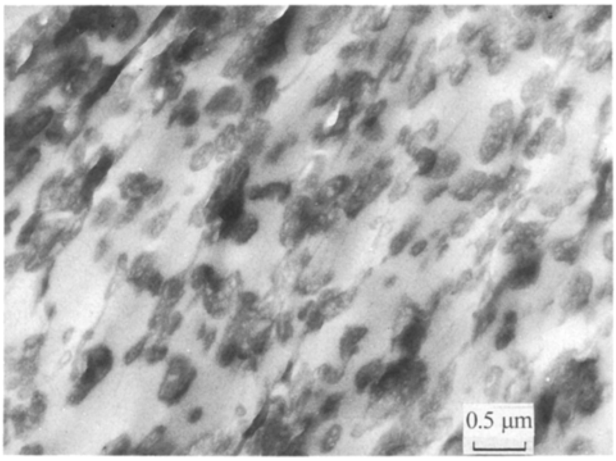

Figure 2 TEM analysis of AES sample (pellet).

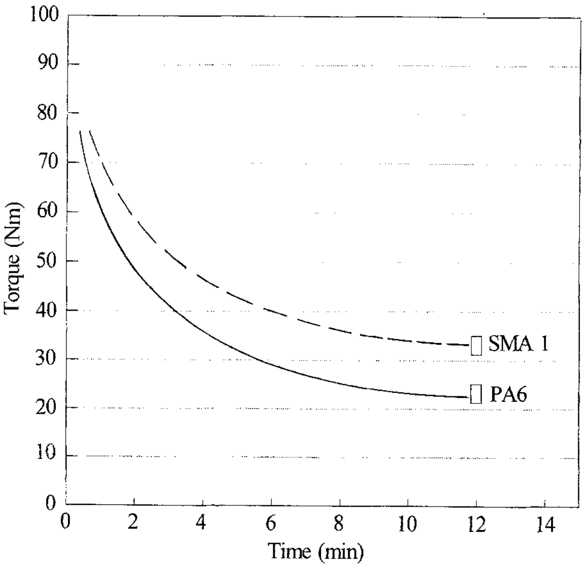

Figure 3 Torque–time evaluation of (—) PA6 and (– – –) SMA1 in Brabender PLE 651 at 220 °C and 60 r.p.m.

2.5. TEM analysis

The TEM analysis of the samples was carried out with a transmission electron microscope (TEM) (Philips EM 301 model), by staining with osmium tetroxide and ultramicrotoming [49].

Samples were cut both from the pellets and from injection-moulded tensile bars.

AES resin is easily detectable because of the presence of EPDM rubber (Fig. 2).

2.6. Crystallinity

Heats of fusion were measured under nitrogen using a differential scanning calorimeter, Perkin Elmer DSC type 7 (rate temperature 10°C $\min^{-1}$). The crystallinity was calculated from the heat of fusion of PA6 area, taking 45.6 cal g^{-1} as the ΔH reference value for PA6 [50].

3. Results and discussion

3.1. PA6/SMA blends

3.1.1. Torque measurements

The MA content in these PA6/SMA samples was kept constant (3% referred to the blend). The blends were prepared in a Brabender Plasticorder, measuring the torque after mixing for 12 min. Observation of the torque value in a Brabender mixer is a simple and reliable tool for evaluating any reaction during melt blending [51], such as cross-linking phenomena, *in situ* formation of graft copolymers, etc.

In processing SMA at 220 °C and 60 r.p.m., the viscosity, and therefore the torque value, is very high in the feeding stage at the beginning of the mastication. When plastification is complete, a plateau is reached; for longer processing times the torque values tend to decrease smoothly owing to a slow polymer degradation (Fig. 3).

The behaviour of single PA6 and single SMA after 12 min mastication has been taken as the "reference" and their profile as the baseline for the following experiments with PA6/SMA blends. The molecular weights, M_w, of both copolymers are roughly the same with 180 000 for SMA3 and 200 000 for SMA1.

The experimental values of torque during processing of the blends are higher than the baseline calculated from the contribution of the single polymers (Table II); thus some chemical reaction has occurred

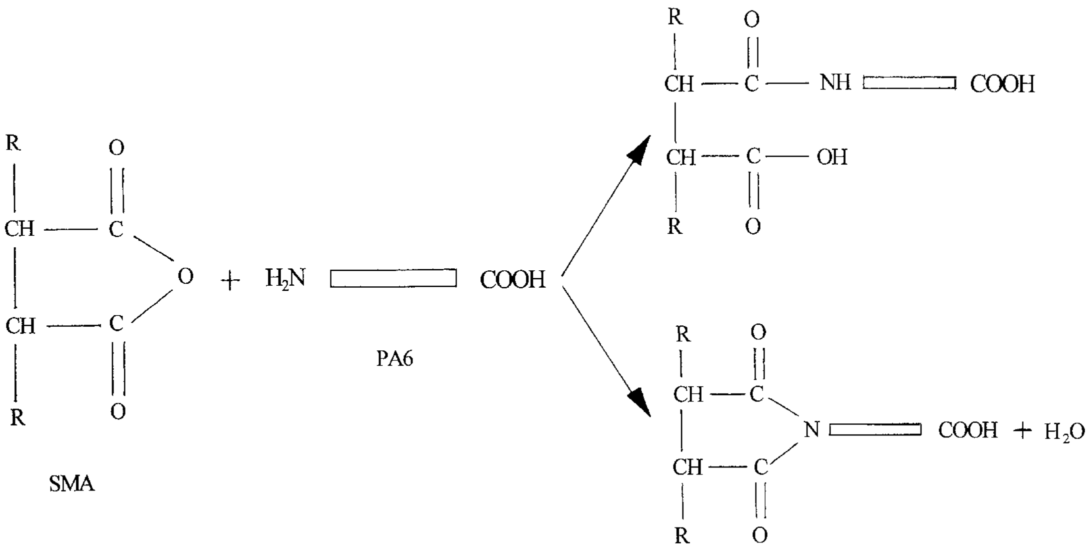

Figure 4 Reaction scheme between PA6 and SMA.

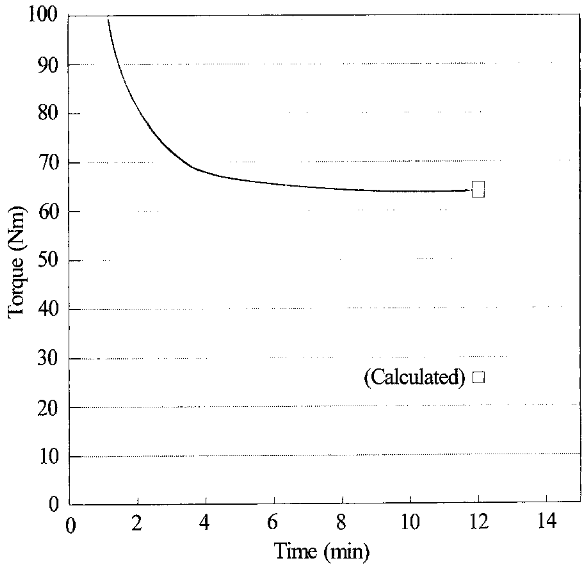

Figure 5 (—) Torque–time evaluation of Sample 1. (□) Calculated.

TABLE II Torque after 12 min mastication

	PA6 (%)	SMA1 (%)	SMA2 (%)	SMA3 (%)	MA (%)[a]	Torque	
						Exp. (Nm)	Calc. (Nm)
A	100	–	–	–	–	24	–
B	–	100	–	–	10.2	32	–
C	–	–	100	–	50	21	–
D	–	–	–	100	23.9	36	–
1	70.6	29.4	–	–	3	64	26.3
2	80.4	19.6	–	–	2	60	25.6
3	94	–	6	–	3	24	23.8
4	96	–	4	–	2	24	23.9
5	87.45	–	–	12.55	3	38	25.5
6	91.6	–	–	8.4	2	35	25

[a] In the blend.

during blending and a certain amount of graft copolymer between maleic anhydride and the terminal amino groups of PA6 should have been formed (Fig. 4) [50, 52]. The increase in torque is particularly outstanding for PA6/SMA1 blend (experimental value of 64 Nm, compared with the expected one of 26.3 Nm) (Fig. 5). A slightly inferior value (60 Nm) is obtained by lowering the SMA1 content from 29.4% to 19.6% (Sample 2). Thus increasing MA content in the copolymer from 10.2% to 23.9% lowers the torque values. The torque value of 38 Nm obtained with Sample 5 is still higher than the calculated 25.5 Nm, but the effect of the reaction appears less remarkable. The difference between the calculated and the experimental values vanishes when using an SMA copolymer with a rather high MA content (50%) (Sample 3).

The above findings suggest a much higher reactivity of SMA1: the higher the MA content, the lower the reactivity with PA6 end groups. This is probably due to the difficulty of PA6 macromolecules reacting with too many MA groups on the same SMA chain. With the same MA content in the blend (3%), PA6 macromolecules have more chances to react with more "diluted" MA groups, as in SMA1, than with more "crowded" ones, as in SMA2 (see Fig. 6).

3.1.2. Phase separation

Samples 1, 3 and 5 were separated according to the scheme shown in Fig. 1. Each blend was extracted with THF, in order to separate the insoluble SMA copolymer, and then with formic acid. Fig. 7 shows IR spectra of SMA1 for reference. The absorption bands, characteristic of maleic anhydride (1780 cm^{-1}), polystyrene (1600 and 700 cm^{-1}) are easily detectable. For the same purpose, Fig. 8 shows IR spectra of PA6, with the absorption bands characteristic of the amide group at 3300, 1544 and 1640 cm^{-1}.

The FT–IR spectrum of the THF fraction of Sample 1 is shown in Fig. 9: the absorption bands characteristic of MA (1780 cm^{-1}), and polystyrene (700 and 1600 cm^{-1}) appear very sharp. No bands typical of PA6 are detectable at 1640 and 3300 cm^{-1}. The FT–IR spectrum of the formic acid fraction of the Sample 1 is shown in Fig. 10: the absorption bands, characteristic of amido groups, are clearly detectable, while there is no trace of SMA copolymer (no band at 1780 cm^{-1}).

The fraction insoluble in THF and then in formic acid shows both bands characteristic of SMA (1780, 700 cm^{-1}) and PA6 (3300, 1640 and 1544 cm^{-1}) suggesting that a number of nylon chains are bonded to the SMA chains to form a SMA-g-PA6 graft copolymer (Fig. 11). Thus, solvent extraction gives results in good agreement with those obtained by torque measurements (Table III). The highest grafting efficiency is achieved with SMA1 (roughly 50% of the copolymer linked to PA6). In Sample 5, about 30% SMA3 has linked to PA6 (THF soluble fraction is 8.3%, compared with 12.55% of the copolymer fed into the mixer). In Sample 3 the copolymer linked to PA6 is hardly detectable.

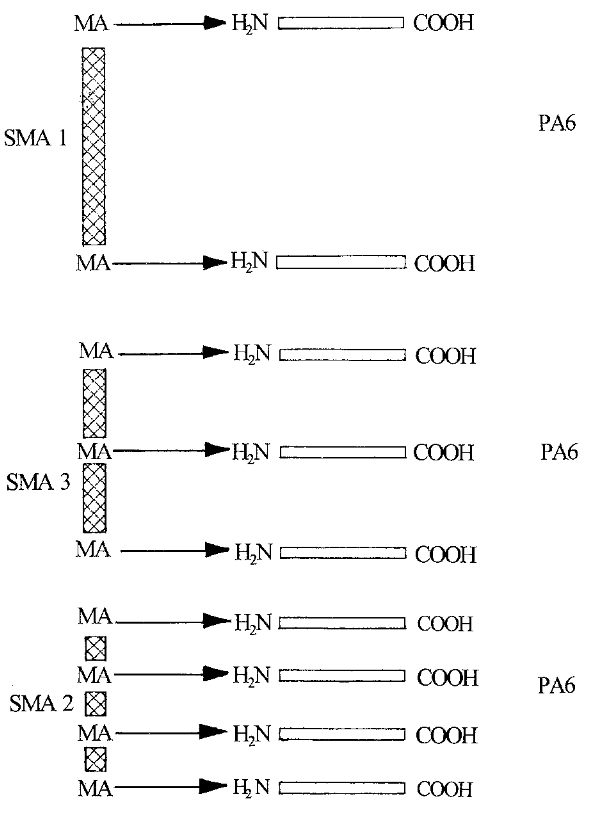

Figure 6 Reaction scheme between SMA and PA6 (3% MA in the blend).

3.1.3. Crystallinity

The heat of fusion of Sample 5, by DSC has been compared with the heat of fusion of PA6, all in the crystalline state (45.6 cal g^{-1}). The percentage crystallinity of the blend was calculated using weighed contributions from the crystallinity values of the pure components. The calculated heat of fusion of Sample 5 is, therefore, 39.88 cal g^{-1}, assuming the SMA copolymer to be completely amorphous.

We have measured a heat of fusion of 32.1 cal g^{-1}, indicating a lower degree of crystallinity for SMA/PA6 blend: the PA6 of the blend should, therefore, have a heat of fusion of 36.71 cal g^{-1}, with a decrease in crystallinity of nearly 20%. This lower degree of crystallinity may be interpreted as the result of the restricted mobility of PA6 chains, chemically grafted on to SMA chains.

3.2. PA6/AES/SMA blends

The composition and the mechanical properties of the blends are given in Table IV. The same ratio between

TABLE III Separation data

	Sample 1	Sample 3	Sample 5
THF soluble (SMA) (%)	15	5.8	8.3
HCOOH soluble (PA6) (%)	38	93.5	71.7
PA6-g-SMA (%)	47	0.7	20

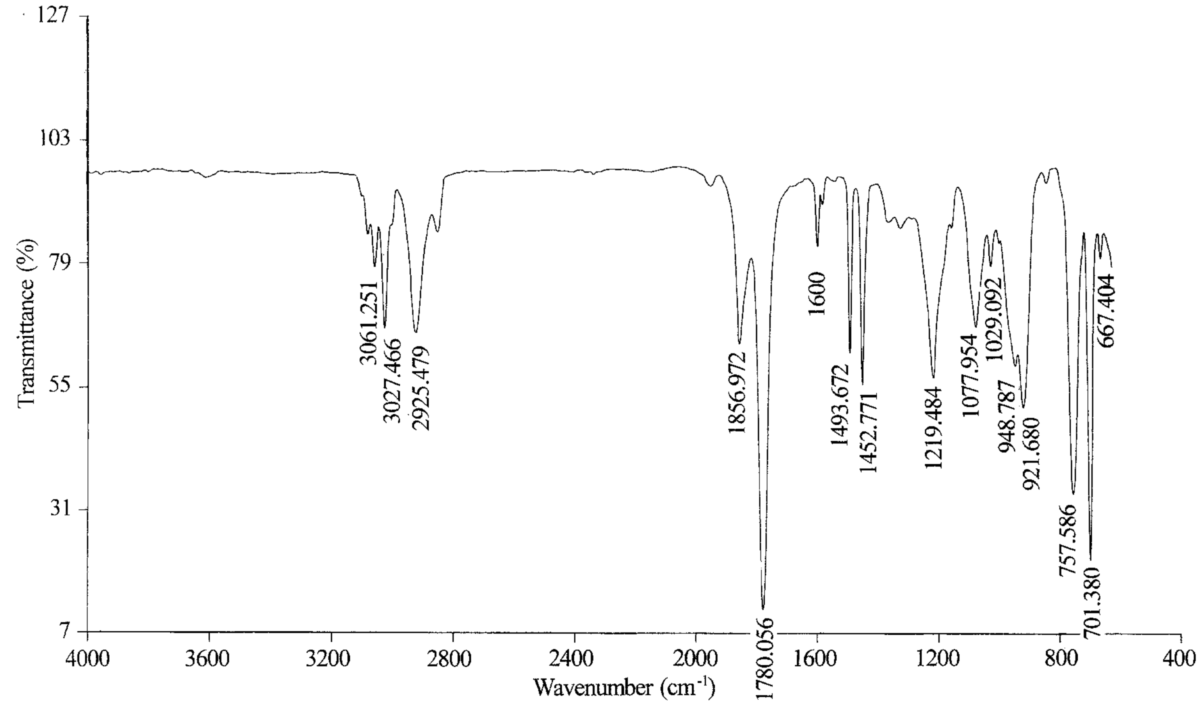

Figure 7 FT–IR spectrum of SMA1.

AES and PA6 (1 : 1) was maintained in the majority of the samples, for investigating different amounts of SMA copolymer.

SMA1 and SMA3 were tested on the basis of the previous results on SMA/PA6 blends in the Brabender mixer. As expected, PA6/AES (reference) blend shows rather poor mechanical properties (notched Izod impact strength = 20 J m^{-1}). The morphology of the pellet consists of rather large domains of AES, easily detectable by EPDM particles, with very poor adhesion with the PA6 phase (Fig. 12).

An injection-moulded specimen (tensile bar) was cut parallel to the flow in order to detect any layer produced by any demixing or coalescence phenomena (Fig. 13). The morphology of the injection-moulded specimens can be described best as exhibiting a quasi-layered or stratified structure with PA6 as the continuous phase: the strata formed by each phase are about 5–15 μm wide and extend more in length. In the bar, the phases are much wider than in the pellet, thus indicating an unstable morphology owing to a very poor interfacial adhesion.

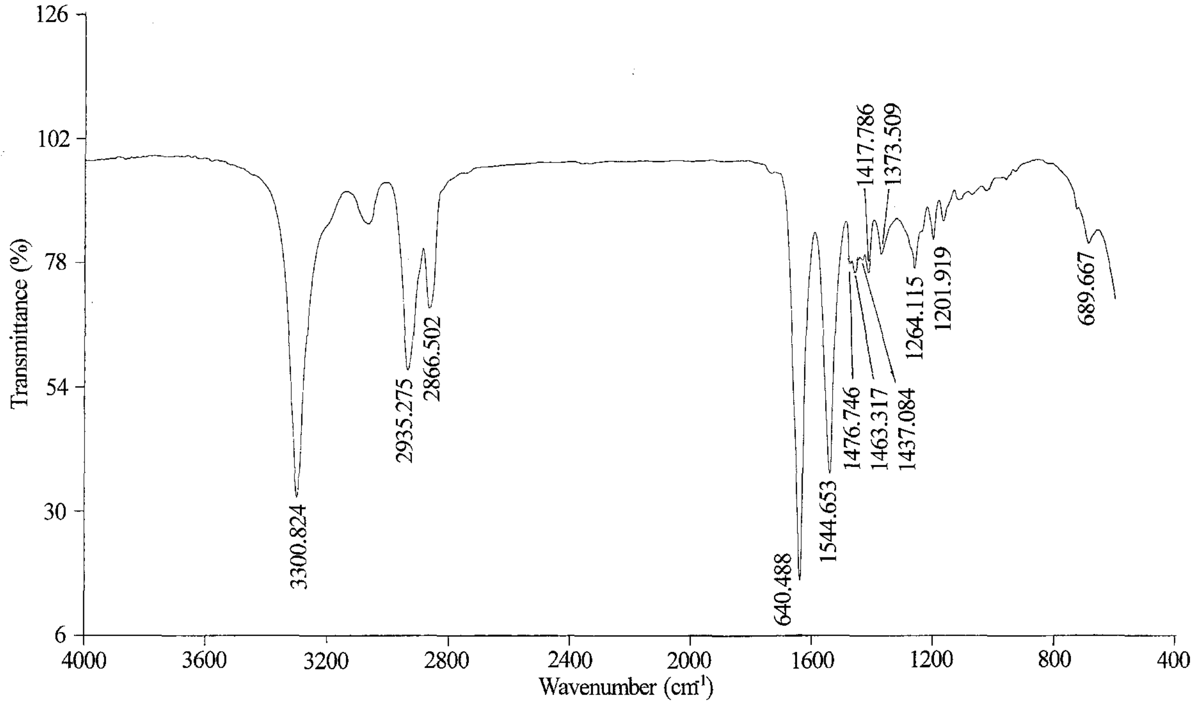

Figure 8 FT–IR spectrum of PA6.

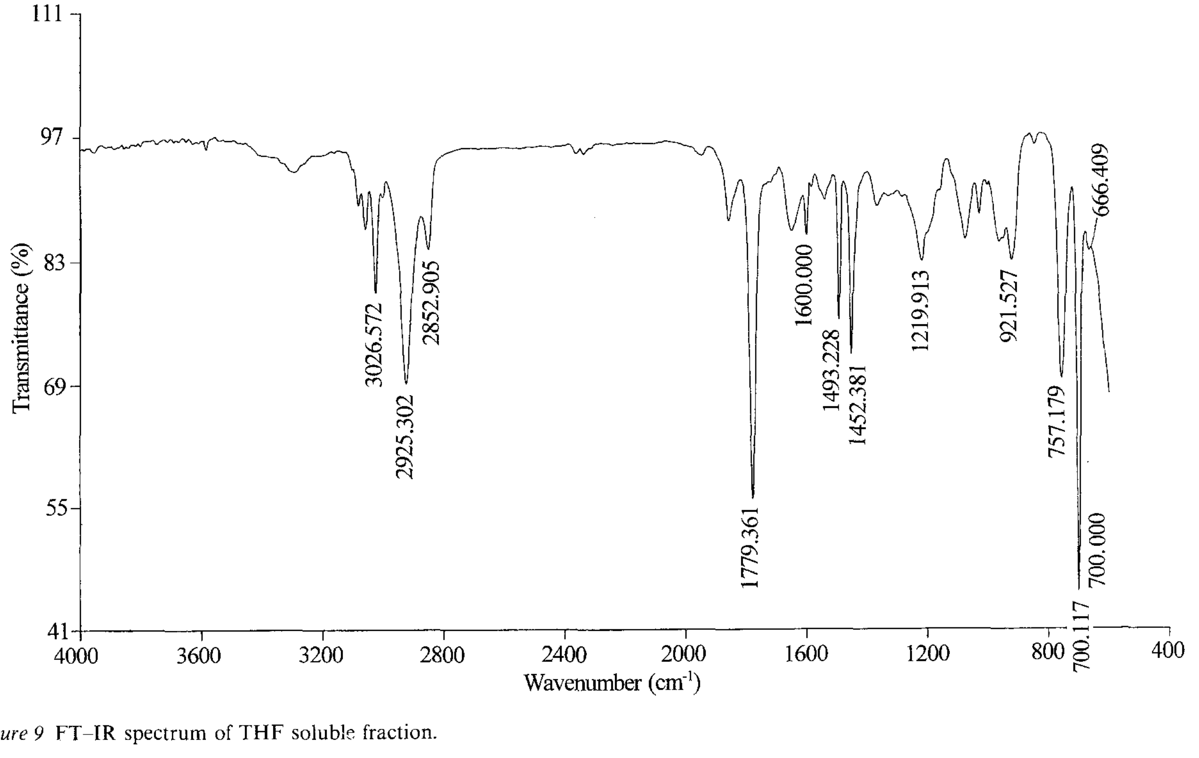

Figure 9 FT–IR spectrum of THF soluble fraction.

On introducing the compatibilizer (SMA3), the mechanical properties are improved and the values of the notched Izod impact strength reaches 110 and 120 J m^{-1} (for 12.7 and 3.2 mm specimens, respectively (Blend 8). The higher amount of compatibilizer and the higher is the impact strength, until a decrease of AES (the toughening agent) becomes evident. An optimum level of compatibilizer (2% MA in the blend) affords the best balance between impact strength and Vicat temperature. The blend with a high amount of compatibilizer (Blend 10 with 30% SMA) shows, in fact, rather poor mechanical properties, quite similar to those of the (reference blend. In Fig. 14 (Blend 8, pellet), AES domains are smaller, compared to those ones in Fig. 12 (no compatibilizer); again PA6 provides the continuous phase. The tensile bar shows the same behaviour (Fig. 15), also with much smaller domains of AES phase, oriented down the flow. Notched Izod impact strength increases with higher amounts of AES (Blend 11) but the Vicat softening temperature decreases (114 °C compared to 180°C).

We have investigated the compatibilizing efficiency of SMA1 (Blend 12), working at fixed AES (65%) and MA (1%) in the blend. This kind of compatibilizer is less efficient, even if the reactivity of SMA1 and PA6 is higher, according to our previous results. Thus, not

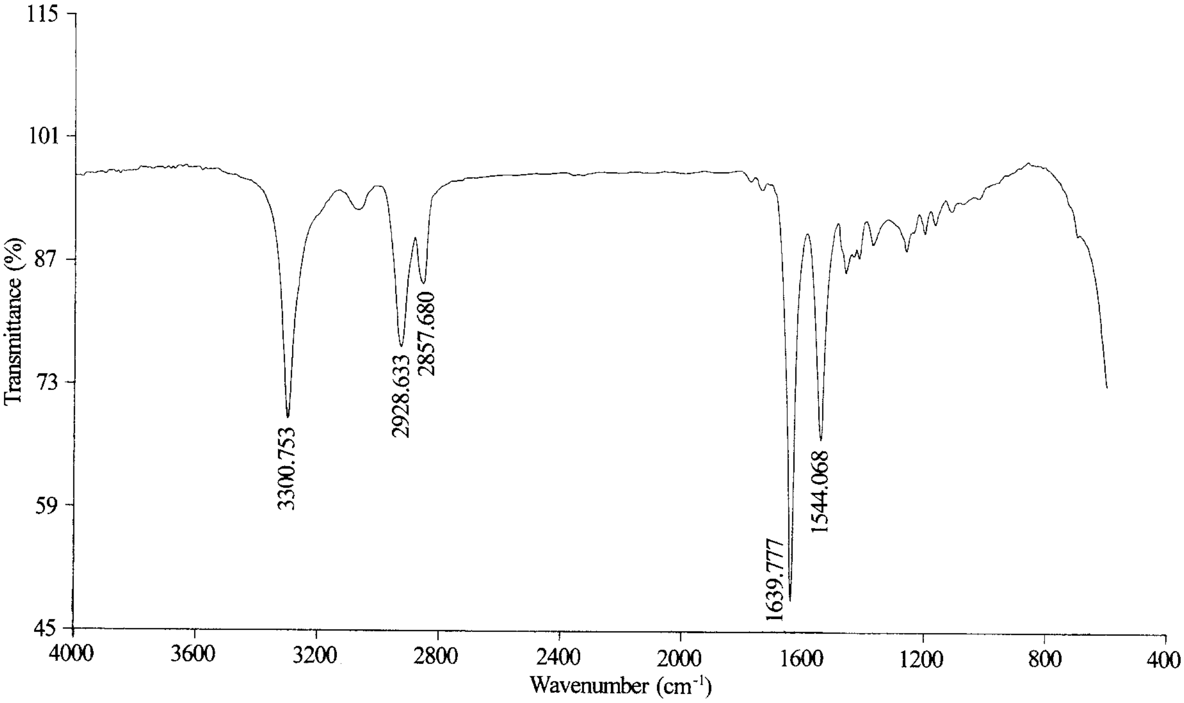

Figure 10 FT–IR spectrum of HCOOH soluble fraction.

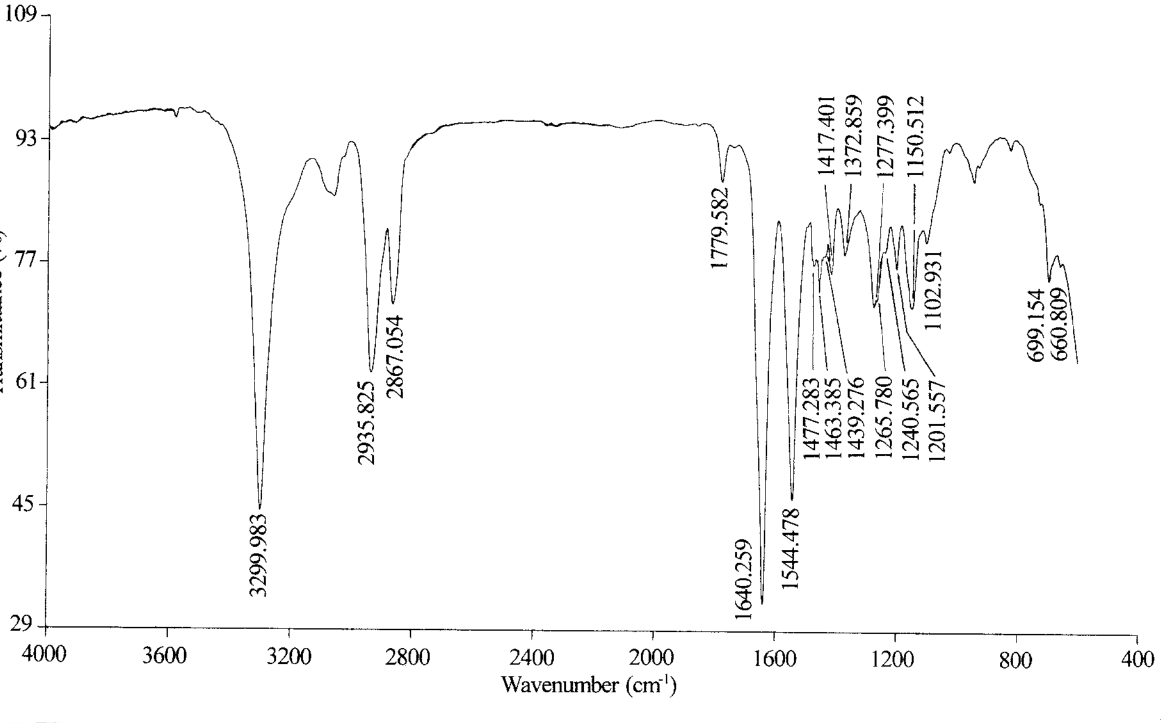

Figure 11 FT–IR spectrum of the insoluble fraction, after extraction with THF and with HCOOH.

only the reactivity towards PA6 but also the miscibility with AES must be taken into account. In fact, SMA is miscible with poly(styrene-co-acrylonitrile) (SAN) phase of AES when the MA content in the former and AN content in the latter are roughly the same [53, 54]. Therefore, compared to SMA3 (24% MA), SMA 1 (10.2% MA) bonds more easily to PA6, but is less miscible with AES, and the corresponding Blend 12 is found to be less tough than Blend 11.

We have also evaluated the compatibilizing efficiency of SMA3, which has been ground to a very fine form (Sample 13 in Table IV). The improvement in

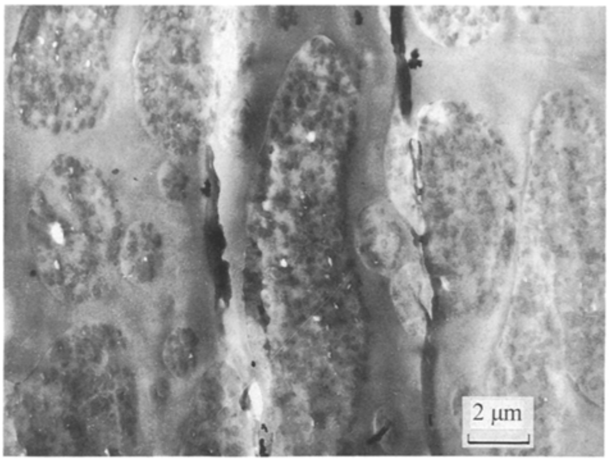

Figure 12 TEM analysis of the reference blend (pellet).

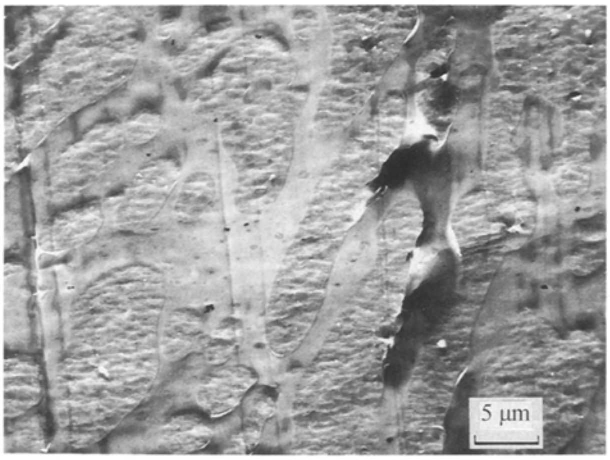

Figure 13 Transmission electron micrograph of the reference blend (tensile bar; direction parallel to flow).

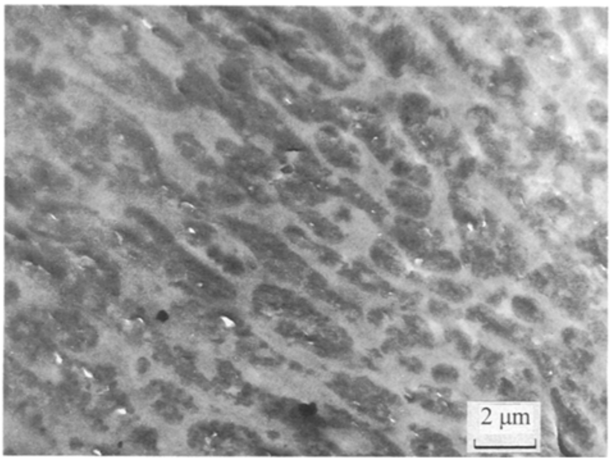

Figure 14 Transmission electron micrograph of Blend 8 (pellet).

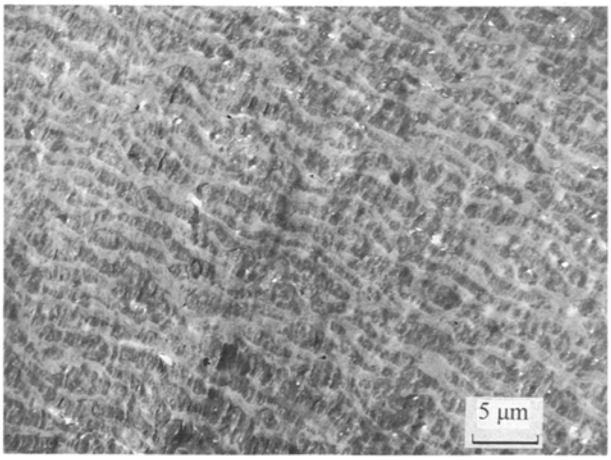

Figure 15 Transmission electron micrograph of Blend 8 (tensile bar, direction perpendicular to flow).

TABLE IV Physical properties of blends

	Reference	Blend						
		7	8	9	10	11	12	13
AES (%)	50	47.9	45.8	43.72	35	65	65	47.9
PA6 (%)	50	47.9	45.8	43.72	35	30.8	25.2	47.9
SMA3 pellet (%)	–	4.2	8.4	12.56	30	4.2	–	–
SMA1 (%)	–	–	–	–	–	–	9.8	–
SMA3 ground (%)	–	–	–	–	–	–	–	4.2
MA in the blend (%)	–	1	2	3	7.8	1	1	1
Notched IZOD impact								
12.7 mm thick ($J m^{-1}$)	20	60	110	85	30	120	80	120
3.2 mm thick ($J m^{-1}$)	22	70	120	100	35	140	90	290
Tensile properties								
Yield strength (MPa)	–	4.3	4.5	4.8	5	–	–	4
Break strength (MPa)	–	3.9	4	4.3	4.4	–	–	4.3
Elongation at break (%)	5	5	30	25	4	–	–	190
Modulus (MPa)	–	205	210	215	235	–	–	200
VICAT soft. temperature (°C)	–	185	180	165	130	114	–	186

mechanical properties is remarkable: notched Izod impact strength reaches 290 and 120 Jm for 3.2 and 12.7 mm, respectively; these values are much higher than those achieved by adding the SMA3 in pellet form with 70 and 60 J m^{-1} for 3.2 and 12.7 mm, respectively. The improvement in elongation at break is even more remarkable (190% compared to 5% reached using the compatibilizer in the pellet).

3.3. Functionalization of AES with MA

The reactive extrusion was performed with MA and DCP in powder form (single step).

In every blend AES resin was dried at 80°C for 24 h, then premixed in a rotary tumbler for 1 h, and subsequently processed.

We have studied the effects of processing conditions on MA grafting efficiency, from two angles: the revolutions per minute and the screw profile. Grafting increased with the addition of higher amounts of MA and DCP, reaching 1% of linked MA (Table V) [55].

An optimum level of grafting does exist (Fig. 16), below or above which Izod impact strength decreases to 550 J m^{-1} at 1% grafted MA. Nevertheless, the tensile properties (e.g. elongation at break) are quite good even with 1% grafted MA. A plateau is reached (Fig. 17) at very remarkable elongation at break (125%–130% compared with 10% of the virgin AES). Therefore, an optimum balance between Izod impact strength and elongation at break can be achieved by using proper amounts of MA and DCP.

3.4. AES-g-MA/PA6 blends

AES-g-MA (50 wt %) described previously was premixed with PA6 (50 wt %) in a rotary tumbler for 1 h and then dried at 80 °C under vacuum for 24 h.

The notched Izod impact strength increased from 20 J m^{-1} (reference blend) to over 1000 and 700 J m^{-1} for 3.2 and 12.7 mm specimens, respectively (Table VI). The maximum impact strength was achieved with 1% MA grafted on to AES resin (Sample 24). Izod impact strength reaches 710 J m^{-1} for the thick specimen and 1050 J m^{-1} for the thin specimen. A plateau seems to exist for MA contents as high as 0.5%. Elongation at

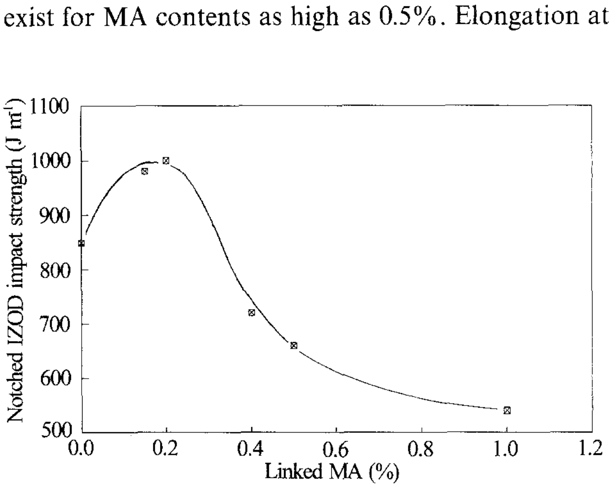

Figure 16 Functionalization of AES with MA and DCP: reactive extrusion.

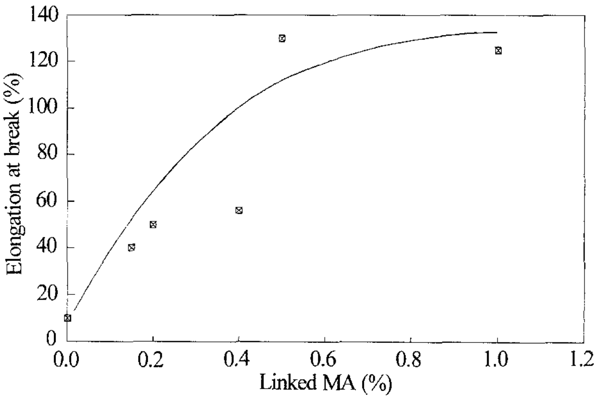

Figure 17 Functionalization of AES with MA and DCP: reactive extrusion.

TABLE V AES functionalization

Sample	AES (%)	MA (%)	DCP (%)	Linked MA (%)	Izod 3.2 mm (J m^{-1})	Elongation at break (%)
14	99.7	0.3	–	–	850	10
15	99.6	0.3	0.1	0.15	990	40
16/A	99.2	0.6	0.2	0.1	–	–
16/B	99.2	0.6	0.2	0.2	1000	50
16/C	99.2	0.6	0.2	0.15	–	–
17	98.5	1	0.5	0.4	720	56
18	98	1	1	0.5	660	130
19	97	2	1	1	550	125

TABLE VI Blends AES-g-MA/PA6 1:1

Sample	MA linked on to AES (%)	Izod 3.2 mm (J m^{-1})	Izod 12.7 mm (J m^{-1})	Elongation at break (%)	Vicat 1 kg (°C)
Reference blend	–	22	20	5	–
20	0.15	220	204	75	191
21	0.2	930	330	120	192
22	0.4	970	400	150	193
23	0.5	1000	700	168	192
24	1	1050	710	170	192

break is quite good, with over 160% compared with 5% (reference blend); the thermal property (Vicat 1 kg softening temperature) is also high (196 °C).

4. Conclusion

The compatibilization of AES and PA6 can be achieved by using SMA or by functionalizing AES in an extruder with MA and DCP. The best mechanical properties are reached by using the reactive extrusion. An outstanding notched Izod impact strength is exhibited by AES-g-MA/PA6 blend (1050 $\mathrm{J\,m^{-1}}$) while maintaining high Vicat softening temperature.

In PA6/SMA/AES blends, the best grafting efficiency to PA6 was found for an SMA sample containing 10% MA, as shown by torque measurements in a Brabender mixer and solvent extraction. But surprisingly, the best compatibilizing efficiency in the AES/PA6 blends was found for an SMA sample with 24% AM, which appears less reactive towards PA6 but more miscible with AES than the former SMA.

In the final blend, notched Izod impact strength increased to 290 $\mathrm{J\,m^{-1}}$ compared with 20 $\mathrm{J\,m^{-1}}$ of the uncompatibilized blend and the Vicat softening temperature was also high (180 °C).

Acknowledgements

We thank Mr. Soregotti for solvent extractions and Dr. Ravanetti for DSC measurements.

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Received 12 May
and accepted 17 November 1992