Compatibility Enhancement of ABS/PVC Blends

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ABSTRACT: The compatibilizing effect of poly(styrene-*co*-acrylonitrile) (SAN) whose acrylonitrile (AN) content is 25 wt % (SAN 25) in poly(acrylonitrile-*co*-butadiene-*co*-styrene) (ABS)/poly(vinyl chloride) (PVC) blend was studied when the AN content of the matrix SAN in ABS was 35 wt % (SAN 35). When some amount of matrix SAN 35 was replaced by SAN 25 in a ABS/PVC (50/50 by weight) blend, the mixed phase of SAN and PVC at the interface was thickened, and about a twofold increase of impact strength was observed. The changes in morphology, dynamic mechanical properties, and rheological properties by the compatibilizing effect of SAN 25 were observed. © 1998 John Wiley & Sons, Inc. J Appl Polym Sci 70: 705–709, 1998

Key words: ABS; SAN; PVC; blend; compatibilizer; impact strength; morphology; thermal property; dynamic mechanical property; rheological property

INTRODUCTION

Polymer blends can combine attractive properties of several polymers into one, or can improve deficient characteristics of a particular polymer. However, immiscible blends often have poor mechanical properties compared to their components. It is well known that the introduction of a small amount of compatibilizer can lead to major changes in mechanical properties.[1,2] It has been reported that a homopolymer as well as block or graft copolymer can be used effectively as a compatibilizer.[3–6]

Poly(acrylonitrile-*co*-butadiene-*co*-styrene) (ABS) is a two-phase system where polybutadiene is dispersed as a minor phase in the matrix of poly(styrene-*co*-acrylonitrile) (SAN). So, in the ABS/poly(vinyl chloride) (PVC) blend, the interaction between SAN and PVC is an important factor for optimum compatibility. The interaction between SAN and PVC is influenced by the acrylonitrile (AN) content in SAN. It has been reported that SAN, containing about 12–26 wt % AN, is miscible with PVC and is immiscible outside this range.[7]

When the AN content of the matrix SAN in ABS is 35 wt %, the impact strength of the ABS/PVC blend showed a large negative deviation from the simple additive value of component polymers. To enhance the impact strength of this blend, we thought that the SAN whose AN content is 25 wt % (SAN 25) as a candidate of a

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Table I Characteristics of Polymers Used in This Study

Resin Notation	Source	Melt Index (g/10 min)	Composition of Monomeric Repeating Unit by Weight
ABS rubber concentrate	Hyosung-BASF	4[a]	Acrylonitrile : butadiene : styrene = 25 : 27 : 48
SAN 35	Hyosung-BASF	60[a]	Acrylonitrile : styrene = 35 : 65
SAN 25	LG Chemical Ltd.	25[a]	Acrylonitrile : styrene = 25 : 75
PVC	LG Chemical Ltd.	55[b]	

[a] Measured at 220°C with 10 kg load.
[b] Measured at 200°C with 10 kg load.

compatibilizer can alleviate the difference in intermolecular interactions of SAN 35 and PVC,[8] because the solubility parameter value of SAN 25 [10.6 (cal/cm^3)$^{1/2}$] lies between those of SAN 35 [11.0 (cal/cm^3)1/2] and PVC [9.8 (cal/cm^3)$^{1/2}$].[9,10] In this article we report our experimental results on this idea.

EXPERIMENTAL

Commercial grades of resins, with the physicochemical properties listed in Tables I and II, were used as received.

Dried resins were hand mixed thoroughly at proper compositions, followed by melt blending using a Buss kneader extruder (BUSS MDK46, L/D = 11) at a zone temperature profile of 180–200°C and 250 rpm. Extrudates were quenched in water and pelletized. Injection molding was done at a temperature similar to that of blending.

$\frac{1}{8}$" Notched Izod impact strength and Vicat softening temperature (VST), at a load of 1 kg, were determined on injection-molded specimen according to the ASTM D256 and D1525.

Morphology of the injection-molded specimen were observed by a scanning electron microscope (SEM, JSM820). SEM micrographs were taken from the cryogenically fractured (in liquid nitrogen) surfaces, which were sputtered with gold before viewing.

Thermal properties were measured by a differential scanning calorimeter (DSC, TA2950). Samples were heated to 200°C and cooled down to the room temperature at a rate of 20°C/min. The glass transition temperature (T_g) and the heat capacity change (ΔC_p) at T_g were measured during the subsequent second heating cycle.

Viscoelastic properties of the blends were measured using an Advanced Rheometrics Expansion System (ARES, Rheometrics). Temperature sweep from 30 to 150°C were made using a stick bar sample, at 3°C/min and 6.28 rad/s. For melt property measurement a cone-and-plate fixture and disk specimen were used. The frequency sweep was done at 170°C and 15% strain, which is the upper limit where the linear viscoelastic behavior was maintained.

RESULTS AND DISCUSSION

The impact strength of blend 1 given in Table III shows a negative deviation from the simple additive value (18.0 kg · cm/cm notch) of ABS and PVC. This seems to be due to the incompatibility

Table II Composition and Physical Properties of ABS and PVC

	ABS 1	ABS 2	ABS 3	PVC
Composition of ABS by weight (ABS rubber concentrate)	60 : 40 : 0	60 : 20 : 20	0 : 0 : 40	—
Melt index, g/10 min	11.4[a]	9.1[a]	7.2[a]	55.0[a]
Notched izod impact strength, Kgf · cm/cm	22.5	28.6	28.6	13.4
Vicat softening temperature, °C	103.9	102.3	104.0	79.2
Flexural modulus, kgf/cm^2	25,538	24,718	23,881	29,539
Flexural strength, kgf/cm^2	772	763	754	901

[a] Measured at 200°C with 10 kg load.

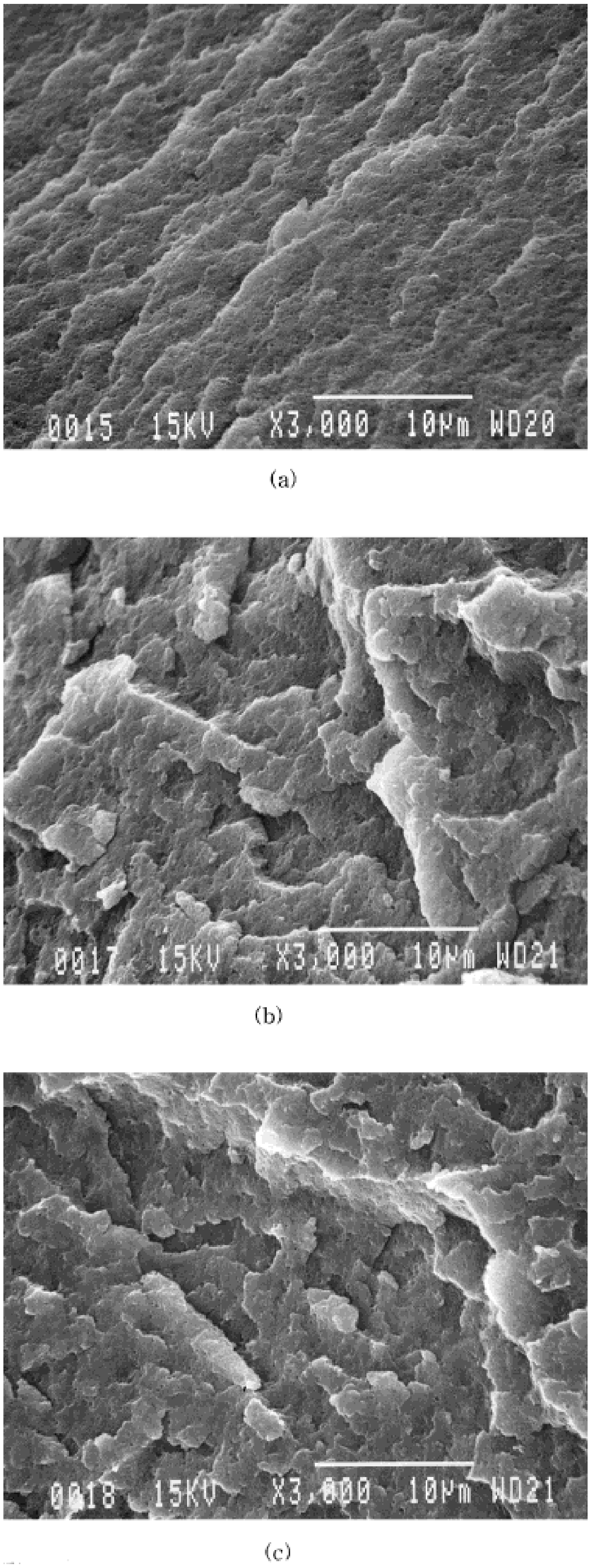
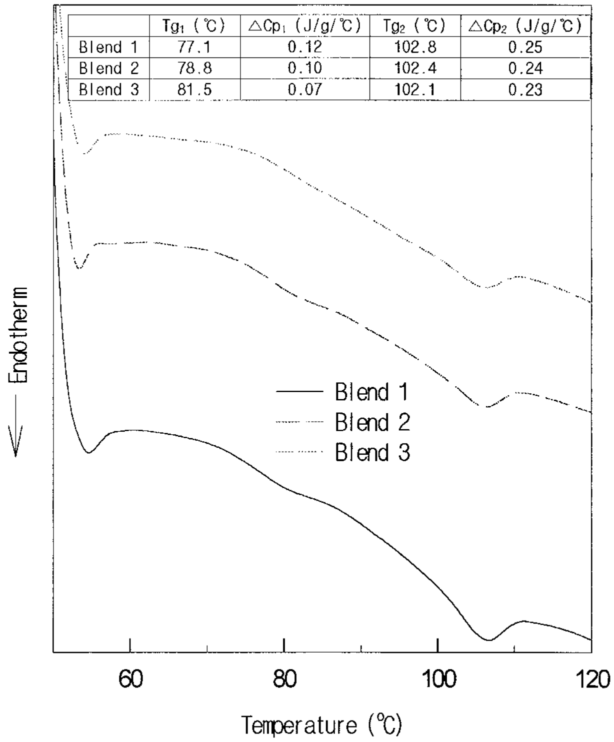


Figure 1 SEM micrographs of fractured surfaces of ABS/PVC blends: (a) Blend 1, (b) Blend 2, and (c) Blend 3.

between SAN 35 and PVC. As some of SAN 35 was replaced by SAN 25 in blends 2 and 3, about a twofold increase of impact strength, and positive deviation from the simple additive values (21.0 kg · cm/cm notch for both blend 2 and blend 3) were attained. This shows the compatibilizing effect of SAN 25.

The stress whitening of all the fractured surfaces after the impact test was generally observed in blends 2 and 3, whereas whitening was not as evident for blend 1. Figure 1 shows the SEM micrographs of cryogenically fractured surfaces of the ABS/PVC blends. The fractured surfaces of blends 2 and 3 are relatively rough, probably due to plastic deformation and tearing during fracturing process, whereas that of blend 1 is relatively smooth, suggesting brittle failure.[11]

Useful information about phase equilibrium in partially miscible multiphase polymer systems can be obtained from thermal properties, such as T_g or ΔC_p.[12–14] The DSC thermograms obtained on heating are shown in Figure 2. All the blends show two separate T_g's of the PVC-rich phase (T_{g1}) and ABS-rich phase (T_{g2}). As some of SAN 35 is replaced by SAN 25 in blends 2 and 3, ΔC_{p1}, ΔC_{p2}, and T_{g2} are decreased, and



	T_{g1} (℃)	ΔC_{p1} (J/g/℃)	T_{g2} (℃)	ΔC_{p2} (J/g/℃)
Blend 1	77.1	0.12	102.8	0.25
Blend 2	78.8	0.10	102.4	0.24
Blend 3	81.5	0.07	102.1	0.23

Figure 2 DSC thermograms of ABS/PVC blends.

Table III Physical Properties of ABS/PVC (50/50 by Weight) Blends

	Blend 1 (ABS 1/PVC)	Blend 2 (ABS 2/PVC)	Blend 3 (ABS 3/PVC)
Melt index, g/10 min.	28.5[a]	25.3[a]	21.9[a]
Notched izod impact strength, Kgf · cm/cm	14.5 (1.7)[b]	31.4 (1.9)[b]	30.4 (1.8)[b]
Vicat softening temperature, °C	97.8 (0.5)[b]	96.0 (0.4)[b]	95.0 (0.5)[b]
Flexural modulus, kgf/cm^2	28,932 (210)[b]	28,338 (200)[b]	28,192 (250)[b]
Flexural strength, kgf/cm^2	864 (3.8)[b]	863 (3.6)[b]	856 (4.5)[b]

[a] Measured at 200°C with 10 kg load.
[b] Standard deviation.

T_{g1} is increased compared with blend 1. This suggests that the mixed phase of PVC and SAN at the interface is somewhat thickened with extended concentration gradient,[15] by the compatibilizing effect of SAN 25.

The results from dynamic mechanical analysis by ARES are given in Figure 3 in terms of storage shear modulus G' and tan δ. Blend 1 shows two separate tan δ peaks of the PVC-rich phase and the SAN-rich phase. As some of SAN 35 is replaced by SAN 25, the tan δ peak of the SAN-rich phase moves to a lower temperature, and the separation of two peaks become obscure. This also supports the existence of a thick interface, as observed by DSC. Early decrease of E' at the transition temperature region by the existence of a mixed phase seems to be the cause of the decrease of VST in blends 2 and 3, as shown in Table III.

The Cole–Cole plot using dynamic data is a useful way of rheological characterization.[16] η'' vs. η' representation in a complex plane gives a circular arc for a miscible blend.[17,18] All three curves shown in Figure 4 drift from a semicircle due to a multiphase structure. However, the early drift of blend 1 is somewhat suppressed in blends 2 and 3. This result also supports the compatibilizing effect of SAN 25 in blends 2 and 3.

CONCLUSIONS

As some of the matrix SAN 35 in ABS/PVC (50/50 by weight) blend is replaced by SAN 25, the compatibility was enhanced, and about a twofold increase of impact strength was attained. This shows the compatibilizing effect of SAN 25, whose solubility parameter value lies

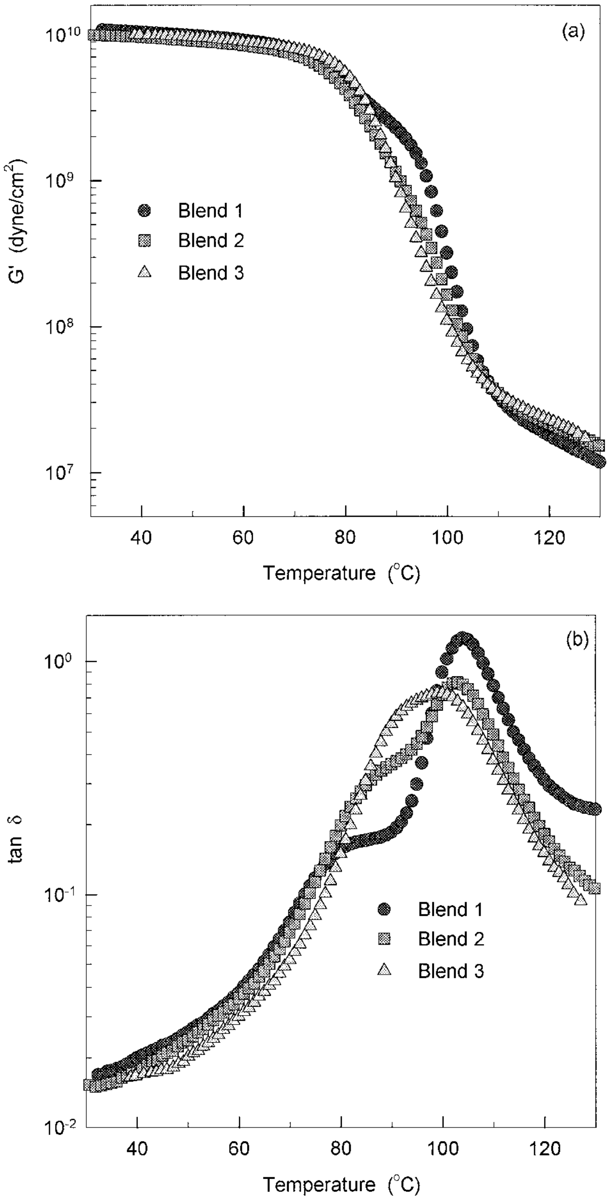


Figure 3 (a) Storage shear modulus and (b) tan δ of ABS/PVC blends.

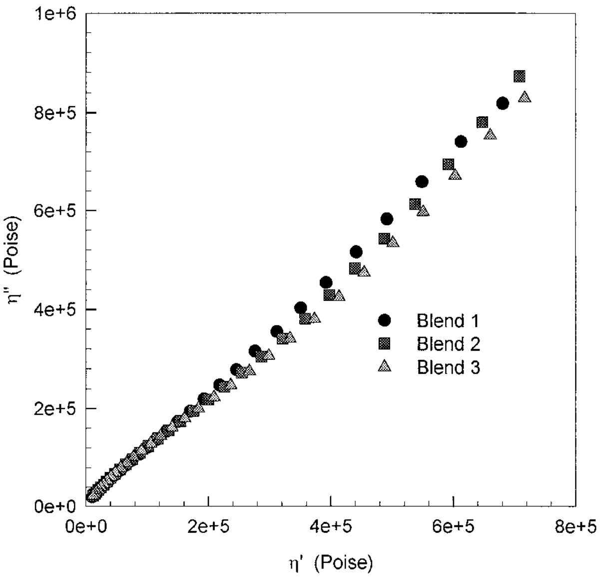


Figure 4 Cole–Cole plot of ABS/PVC blends.

between those of SAN 35 and PVC, in the ABS/PVC blend when the matrix polymer of ABS is SAN 35.

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