

Rheological and Mechanical Properties of Compatibilized Polystyrene/Ethylene Vinyl Acetate Blends

L. W. Tang,¹ K. C. Tam,¹ C. Y. Yue,¹ X. Hu,² Y. C. Lam,¹ L. Li¹

¹School of Mechanical and Production Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798, Republic of Singapore

²School of Materials Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798, Republic of Singapore

Received 6 April 2004; accepted 11 June 2004

DOI 10.1002/app.21151

Published online in Wiley InterScience (www.interscience.wiley.com).

ABSTRACT: In this study, a blend of polystyrene (PS)/ethylene vinyl acetate (EVA) (PS/EVA, 90 : 10 wt %) was compatibilized with three different block copolymers, in which their end blocks were compatible with either styrene or EVA. The compatibilized blends with different compositions were prepared using a twin-screw extruder and injection molded into the required test specimens. Mechanical properties of the blends, such as tensile properties and Charpy impact strength, morphology of tensile fractured surfaces, rheological properties, and thermal properties, were investigated. The results show that the interaction

between the dispersed and continuous phase can be improved by the addition of a compatibilizer. Appreciable improvement in the impact strength of the blend with 15 wt % of compatibilizer C (polystyrene-*block*-polybutadiene) was observed. Its mechanical properties are comparable to those of the commercial high-impact polystyrene, STYRON 470. © 2004 Wiley Periodicals, Inc. *J Appl Polym Sci* 94: 2071–2082, 2004

Key words: PS/EVA blends; compatibilization; mechanical properties; morphology; block copolymers

INTRODUCTION

Toughness is often a deciding factor in material selection for many engineering applications. Consequently, rubber toughening is often used to overcome the brittleness of glassy polymers such as polystyrene (PS). High-impact polystyrene (HIPS) consists of two phases: a glassy PS matrix and a rubbery dispersed phase. A major improvement in toughness is obtained where crosslinked rubber particles (0.1–1.0 μm in diameter), whose surface is grafted with PS, are well dispersed in the PS matrix.¹ Because most rubbers are immiscible with PS, the key to obtaining HIPS is the formation of effective bonding between the PS matrix and the rubbery phase.

Major techniques for improving the impact strength of a polymer blend at the postpolymerization stage generally involve the use of a compatibilizer.^{2,3} Because PS is immiscible with most types of rubbers, attempts at rubber toughening of PS usually involve the use of graft polymerization or a compatibilizer. It has been reported in the literature that block and graft copolymers enhanced the interfacial interaction in binary blends.^{4,5} These copolymers usually contain seg-

ments that are chemically identical or similar to the homopolymers used in the blends.

The goal of compatibilization is to obtain a stable dispersion that will lead to the desired morphology and properties. Successful compatibilization will be able to (1) reduce interfacial energy, (2) permit finer dispersion during mixing, (3) enhance the stability of dispersion against agglomeration or phase separation throughout the processing/conversion to the final product, and (4) improve the interfacial adhesion. Compatibilization can be achieved by (1) addition of linear or star-shaped block copolymers; (2) addition of graft or random copolymers; (3) coreaction within the blend to generate *in situ* either copolymers or interacting polymers; (4) using an interpenetrating polymer network (IPN) technology; (5) crosslinking the blend ingredients; or (6) modification of homopolymers, through incorporation of acid/base groups, hydrogen bonding groups, charge-transfer complexes, and ionic groups, for example.

Both theoretical and experimental studies on the immiscible polymer pair, polystyrene/ethylene vinyl acetate (PS/EVA), to produce HIPS are beginning to emerge.^{6–9} Barbosa et al.^{6,7} and Soares et al.⁹ studied the influence of a nonreactive compatibilizer, EVA-*g*-PS, on the mechanical and morphological properties of PS and the blends with EVA copolymers, whereas de Almeida et al.⁸ investigated the possibility of improving the miscibility of EVA

Correspondence to: K. C. Tam (mkctam@ntu.edu.sg).

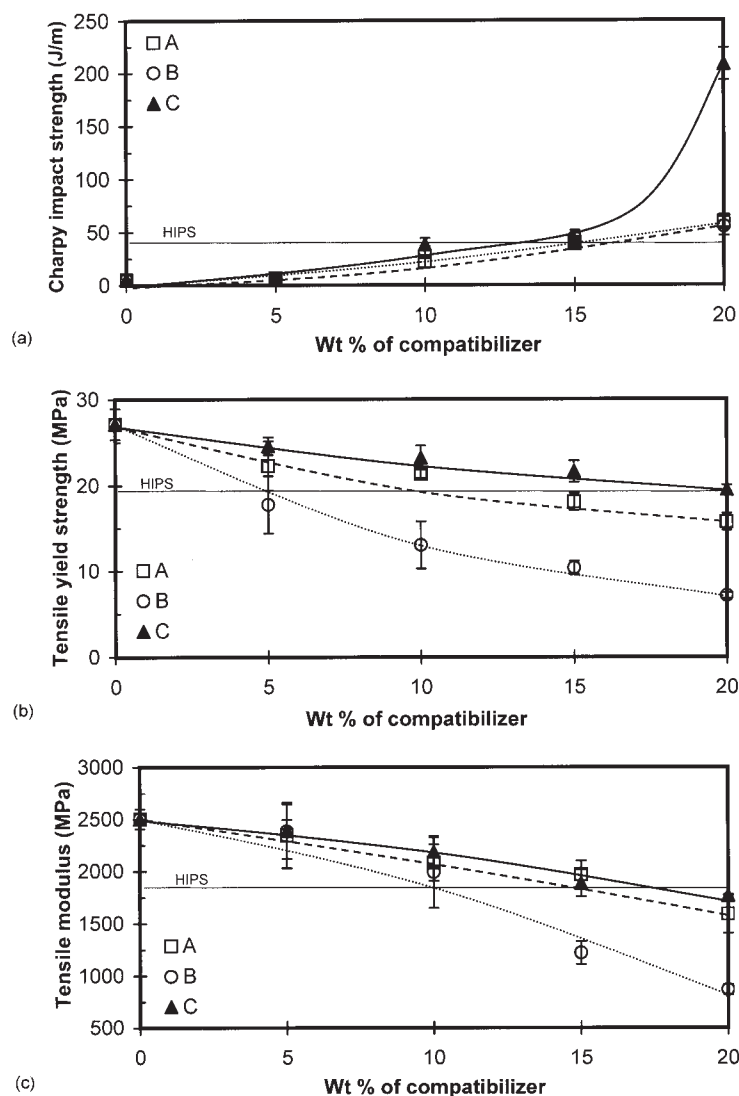


Figure 1 Mechanical properties of compatibilized PS/EVA blends as functions of the type and content of the compatibilizer.

in PS by introducing zinc sulfonate and sodium sulfonate groups onto PS.

The results obtained from our previous studies showed that PS and EVA are immiscible.^{10–12} In the previous study,¹² three types of EVAs with the same vinyl acetate (VA) content (i.e., 27.2–28.8 wt %) but with

different melt flow indices (MFI, g/10 min), ranging from 365 to 440 (ELVAX 210), 38.0–48.0 (ELVAX 240), and 2.6–3.4 (ELVAX 265), were melt blended with PS. The results showed that ELVAX 265 (EVA265) is the most effective impact modifier for PS. To further improve the toughness of this blend, while maintaining its excellent tensile property, compatibilization is necessary. In this study, the effect of compatibilization on the blend by incorporating 10 wt % of EVA was examined. Three compatibilizers whose end blocks are either miscible or semimiscible with styrene and EVA were selected and the effect of compatibilizers content was studied. Moreover, 10 wt % of the chosen compatibilizers was also added to PS only to study their effects on PS alone. The three compatibilizers chosen for this study are:

1. Compatibilizer A: Polystyrene-*block*-poly(ethylene-*ran*-butylene)-*block*-polystyrene-*graft*-maleic anhydride

TABLE I
Comparison of the Mechanical Properties of HIPS and the Blend Added 15 wt % of Compatibilizers A, B, and C

Sample	Tensile yield strength (MPa)	Tensile modulus (MPa)	Charpy impact strength (J/m)
HIPS	19.69	1818	42.21
P10E265/15A	18.09	1970	38.55
P10E265/15B	10.35	1220	44.62
P10E265/15C	21.63	1886	41.26

TABLE II
Fracture Characterization of the Compatibilized PS/EVA Blends

Sample	Fracture characterization				Fracture type
	2 halves/linked	Crack propagation type	Fracture surface texture	Crazing	
5% A	2 halves	Straight	Very slight roughness	No	Brittle
10% A	2 halves	Slight branching	Slight roughness	No	Brittle-ductile
15% A	2 halves	Branched	Rough	No	Ductile
20% A	Linked	Branched	Rough	No	Ductile
5% B	2 halves	Very slight branching	Smooth	No	Brittle-ductile
10% B	Linked	Slight branching	Slight roughness	No	Ductile-brittle
15% B	Linked	Branched	Rough	No	Ductile
20% B	2 halves	Straight	Slight roughness	No	Brittle
5% C	2 halves	Straight	Very slight roughness	No	Brittle
10% C	2 halves	Straight	Rough	No	Brittle-ductile
15% C	2 halves	Branched	Rough	No	Ductile
20% C	2 halves	Straight	Rough	Yes	Ductile

- Compatibilizer B: Polystyrene-*block*-polyisoprene-*block*-polystyrene
- Compatibilizer C: Polystyrene-*block*-polybutadiene

These three compatibilizers have different kind of structures. Compatibilizer A is a triblock copolymer with a maleic anhydride group grafted onto PS. This is the first attempt where we introduced such a reactive group in the PS/EVA blends. Compatibilizers B and C are tri- and diblock copolymers, respectively. It was found that diblock copolymers are more efficient than triblock and graft copolymers.^{3,4,13-15}

EXPERIMENTAL

Materials

The system investigated in this study consisted of a matrix of PS (STYRON 666H; MFI of 8.0 dg/min), supplied by Dow Chemical Co. (Midland, MI); a minor phase of EVA with VA content 27.2–28.8% by weight, manufactured by Du Pont (ELVAX 265, MFI of 2.6–3.4 dg/min); and three types of compatibilizers: compatibilizer A [polystyrene-*block*-poly(ethylene-*ran*-butylene)-*block*-polystyrene-*graft*-maleic anhydride, MFI of 22 dg/min]; compatibilizer B (polystyrene-*block*-polyisoprene-*block*-polystyrene, MFI of 106 dg/min); and compatibilizer C (polystyrene-*block*-polybutadiene, MFI of <1 dg/min), supplied by Aldrich Chem-

ical Co. (Milwaukee, WI). The mechanical properties of the compatibilized PS/EVA blends studied in this project were compared with those of a commercial HIPS (STYRON 470) supplied by Dow Chemical Co.

Preparation of blends and test samples

Three compatibilizers, A, B, and C were separately added to the PS/EVA (90 : 10 wt %) blend at concentrations of 5, 10, 15, and 20 wt %. (The uncompatibilized PS/EVA (90 : 10 wt %) blend was designated as P10E265 and if 5 wt % of compatibilizer A was added, the compatibilized blend was designated as P10E265/5A, and so forth.) For comparison and to investigate the effect of compatibilizers as an impact modifier for PS, the PS was also blended with the three compatibilizers, respectively, in the proportion of 90 to 10% by weight. (The corresponding blend was noted as PS/A if compatibilizer A was added to PS.)

The polymers were melt-blended in a corotating twin-screw extruder (Rheocord 90; Haake, Bersdorff, Germany) at a rotor speed of 10 rpm. Temperature zones were set at 80, 100, 140, 170, and 180°C. The extrudate was then quenched in a water bath and subsequently pelletized. The pellets were dried in the oven for 24 h at 60°C and injection molding was carried out using a Manumold 77/30 (Manumold, Bucks, UK) at 200°C to obtain ASTM standard test samples for tensile, Charpy impact, dynamic mechanical analysis (DMA), and rheology testing.

TABLE III
Classification of Fracture Characterization

	Brittle fracture	Ductile fracture
Nature of sample break	Into 2 halves	Hinged; not complete break
Crack propagation	Straight crack	Branched break
Fracture surface	Smooth fracture surface	Rough fracture surface
Crazing	No crazing	Crazing occurs

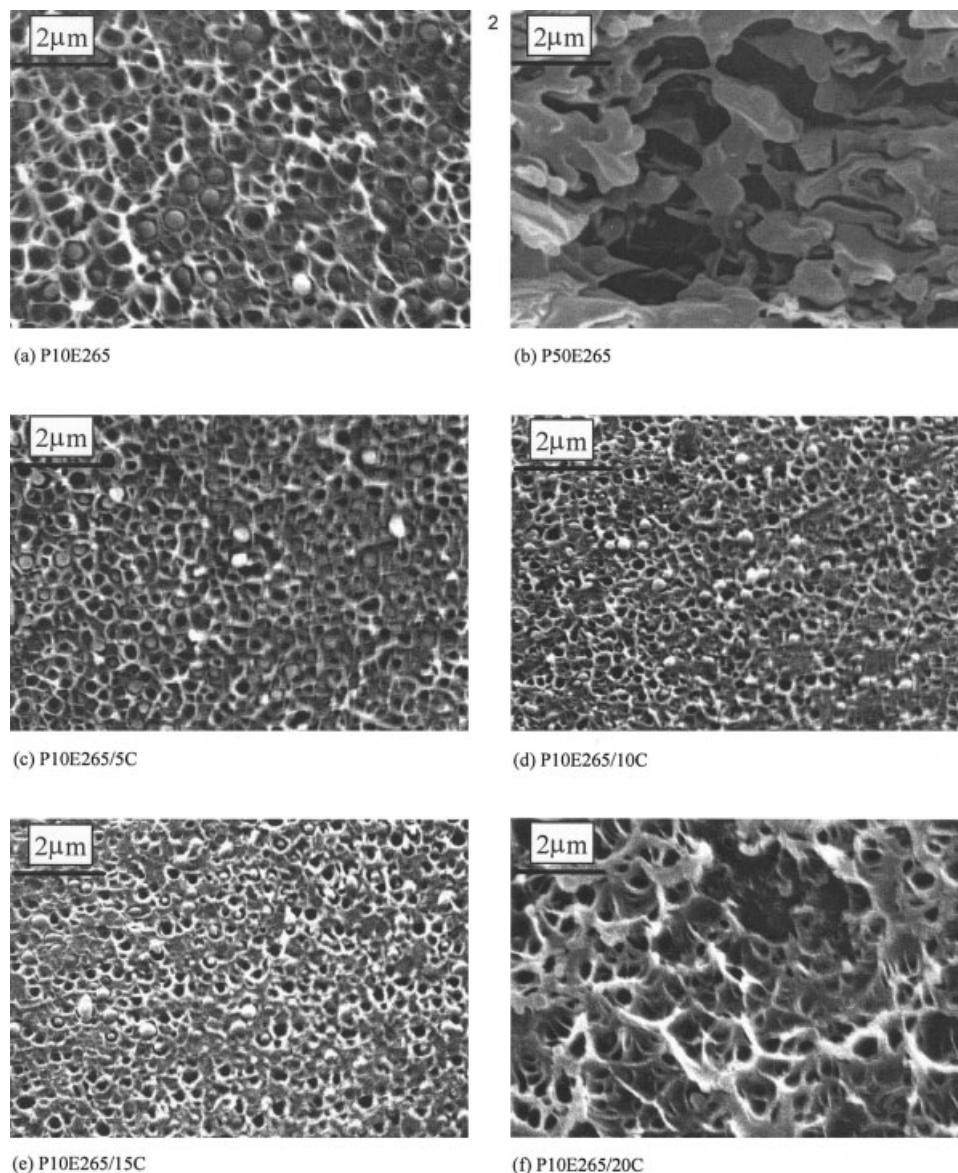


Figure 2 Tensile fractured surfaces of HIPS, PS, and uncompatibilized and compatibilized PS/EVA blends.

Mechanical testing

Tensile testing (ASTM D638) was performed on dumbbell-like specimens at room temperature (25°C) using the Instron 4302 tensile testing machine (Instron Corp., Canton, MA) with a 10-kN load cell. A cross-head speed of 5 mm/min and an extensometer of 50-mm gauge length were used to obtain tensile yield strength and tensile modulus. The average and standard deviations of 10 test pieces of each blend were determined.

The Charpy impact test (ASTM D256) was conducted at room temperature (25°C) with notched test samples of notch width 4 mm in a Dynatup POE200 pendulum impact test machine (Instron Corp.) to obtain impact energies. A pendulum weight of 0.898 kg and strike angle of 90° were used. The average and

standard deviations of 10 test pieces for each blend were determined.

Morphological studies

The tensile fractured surfaces of the test samples were cut to a thickness of about 5 mm and attached to the substrate using a carbon tape. They were then gold coated by a gold-sputtering machine and studied on the scanning electron microscope (SEM; JSM-5410LV, JEOL, Tokyo, Japan), at an electrical high tension (EHT) of 20 kV and a fixed magnification of $\times 5000$ for consistency to facilitate comparison of droplet size.

Dynamic mechanical analysis

Dynamic mechanical analysis (DMA) was carried out using a DMA2980 apparatus (TA Instruments, New

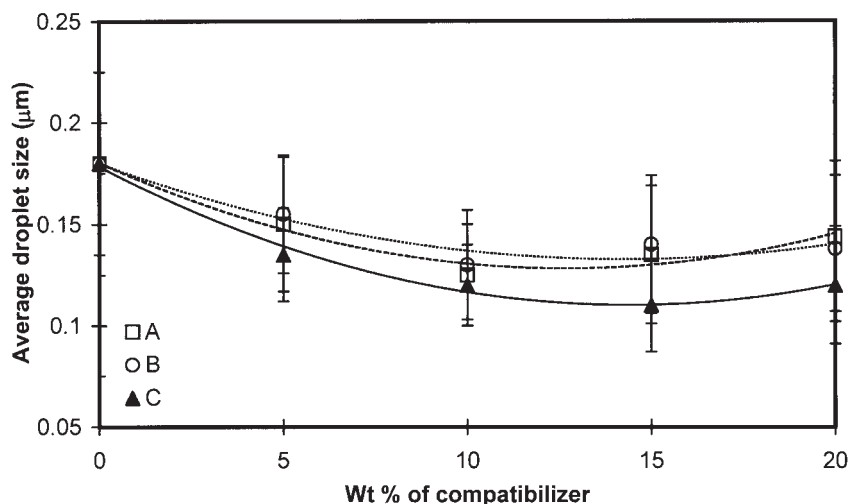


Figure 3 Variation of average droplet size with varying amounts of different compatibilizers.

Castle, DE) in which liquid nitrogen was used as the purge gas. The samples were injection molded, with dimensions around $35.0 \times 3.175 \times 12.7$ mm, and a dual-cantilever clamp was used to mount the sample. The initial temperature was set at -100°C and kept at that temperature for 5 min before heating to 150°C at a ramping rate of $3^{\circ}\text{C}/\text{min}$. The frequency and amplitude used were 1 Hz and $30 \mu\text{m}$, respectively.

Rheological testing

Rheological properties of the compatibilized polymer blends were examined using an ARES mechanical spectrometer (Rheometric Scientific, Piscataway, NJ). For this experiment, a 25 mm diameter cone-and-plate geometry was used. The cone angle was 0.1 radian. Dynamic frequency sweep tests were then carried out under a strain of 10.0% for all the samples. The initial frequency was set at 100 rad/s and the final frequency was set at 0.3 rad/s. Thirteen different frequencies at five different temperatures (170, 180, 190, 200, and 210°C) were examined for each sample. The rheological measurements were maintained within the linear viscoelastic region. Finally, a steady rate sweep test was carried out at five different temperatures. The initial and final rate was set at 1.01 and 0.03/s, respectively. The sample was presheared for 20 s, after which the measurement was collected for 10 s.

RESULTS AND DISCUSSION

Effect of compatibilizer content

Mechanical properties

As can be seen from Figure 1, the general trend for all three compatibilizers is that an increase in the Charpy impact strength and a corresponding decrease in ten-

sile yield strength and tensile modulus are observed with the addition of compatibilizer to the PS/EVA (90/10) blend.

At 5 wt % compatibilizer, a slight improvement in the impact strength was observed for all three compatibilizers [Fig. 1(a)]. However, on adding a compatibilizer of 10 wt %, there was a significant improvement in the impact properties of the blends, with the impact strength increasing four- to eightfold, with compatibilizer C exhibiting the best results. On further addition of compatibilizer to 20 wt %, there was a further improvement in the impact properties. In the case of compatibilizer C, there was another sudden increase in the impact strength (from 41.26 to 208.35 J/m). To explain this, the results of addition of compatibilizer to PS should be noted. It is shown that compatibilizer C by itself is an effective impact modifier. This will be elaborated further in a later part of the discussion.

By examining the tensile properties, a general decrease in the tensile yield strength [Fig. 1(b)] and tensile modulus [Fig. 1(c)] is evident in all three compatibilizers. Compatibilizer B shows the poorest results, with a substantial decrease in both the tensile yield strength and tensile modulus on addition of compatibilizer. Thus, compatibilizer B is unsuitable for this blend with respect to the tensile properties. For the remaining two compatibilizers, C seems to show slightly better results than those of A. Compatibilizer A's tensile properties are acceptable up to 15 wt % composition (tensile yield strength and tensile modulus decreasing to 15.72 and 1590 MPa, respectively, at 20 wt %) and compatibilizer C's tensile properties are acceptable up to 20 wt %.

These results again show that a diblock copolymer (i.e., compatibilizer C) is more efficient than either a triblock or graft copolymer.^{3,4,13-15} Compatibilizer A is

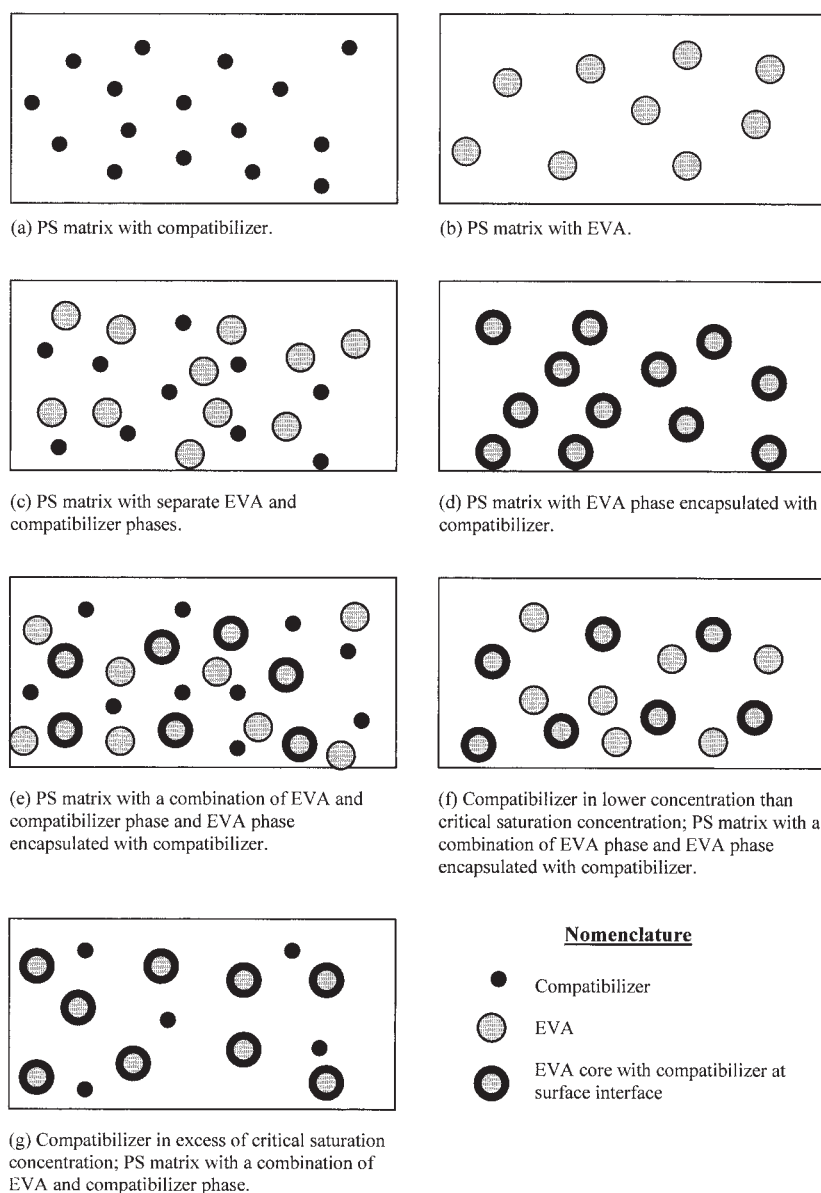


Figure 4 Pictorial representation of a compatibilization model.

better than compatibilizer B because the reactive maleic anhydride group is an effective modifier for blends prepared from mixtures of polar and nonpolar polymer components.^{16–19} Because compatibilizer A is a triblock copolymer and the maleic anhydride group is actually grafted onto PS, it is not as effective as compatibilizer C.

As shown in Figure 1, an impact strength comparable to that of HIPS can be achieved with about 10 to 15 wt % compatibilizers A and C, respectively. Thus, to achieve both tensile and impact properties comparable to those of HIPS, 10 to 15 wt % of compatibilizer A or C should be added to the base composition of the PS/EVA blend. From the data, compatibilizer C is the most promising among the three (Table I). It is also noteworthy that the blend of 20 wt % compatibilizer C

shows an impact strength approximately five times that of HIPS, whereas its tensile properties are still comparable with those of HIPS.

Characterization of fracture surfaces

In terms of fracture characterization, results have to be interpreted carefully. Basically such characterization provides an overall assessment on the effectiveness of compatibilization and its effects on the morphology. From Tables II and III, the general trend observed is the increase in the ductility with increasing amounts of compatibilizer. This shows that the compatibilizer is effective in changing the morphology of the blends.

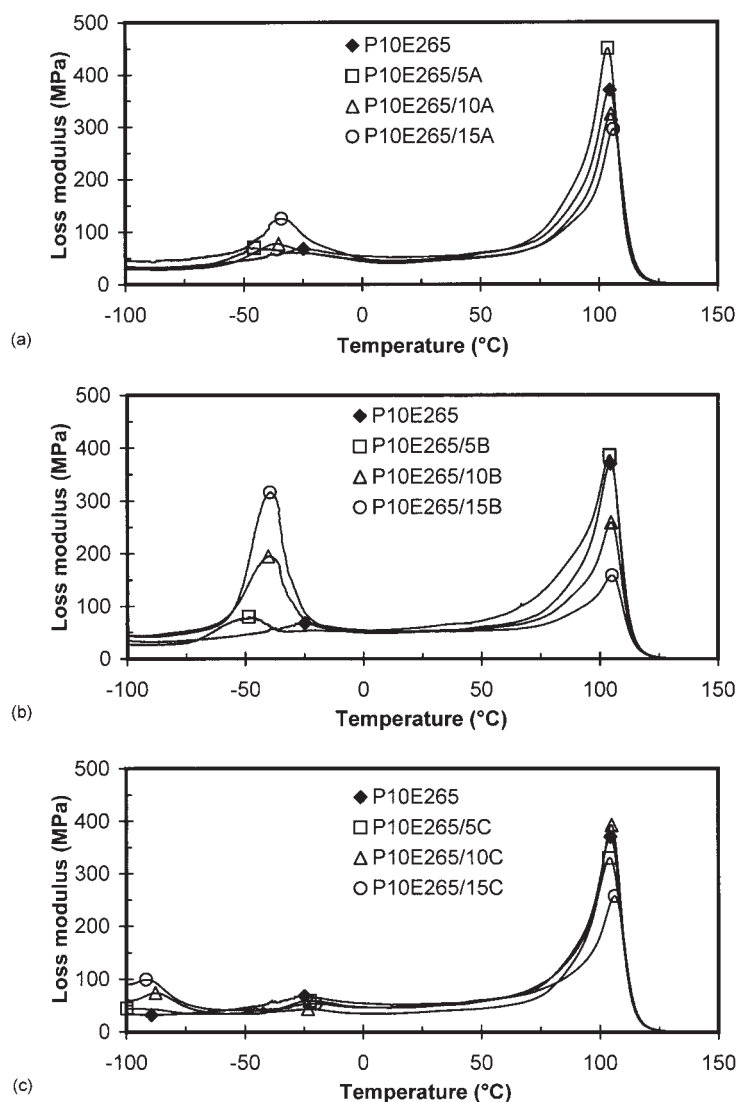


Figure 5 Effect of increasing the amount of compatibilizer in the blend P10E265: (a) compatibilizer A, (b) compatibilizer B, and (c) compatibilizer C.

Morphological studies

SEM micrographs of P10E265, P50E265, and one of the compatibilized PS/EVA blends are shown in Figure 2. The corresponding droplet size of the three compatibilized systems is shown in Figure 3.

For the blend loaded with 20 wt % of compatibilizer C [Fig. 2(f)] and the other two compatibilizers (SEM micrographs are not shown here), we could see a substantial change in the morphology of the tensile fractured surface. The morphology of this composition is quite similar to that of the uncompatibilized blend with a high proportion of EVA, as shown in Figure 2(b). The similarity of these compositions for both uncompatibilized and compatibilized blends is that their impact strength was significantly improved.

From the variation in the droplet size (Fig. 3), the general trend is that the droplet size decreases with

TABLE IV
Comparison of T_g Values

Sample	T_g of EVA (°C)	T_g of PS (°C)
HIPS	-76.8 ^a	98.0
PS	—	100.2
EVA	-20.2	—
P10E265	-25.7	104.6
P10E265/5A	-48.0	103.6
P10E265/10A	-37.3	105.0
P10E265/15A	-34.1	105.9
P10E265/5B	-48.7	103.8
P10E265/10B	-40.0	104.7
P10E265/15B	-40.0	105.4
P10E265/5C	-23.5	103.8
P10E265/10C	-22.5	104.9
P10E265/15C	-21.0	106.0

^a This is actually the T_g for the elastomer phase (PBR) that dispersed into a PS matrix.

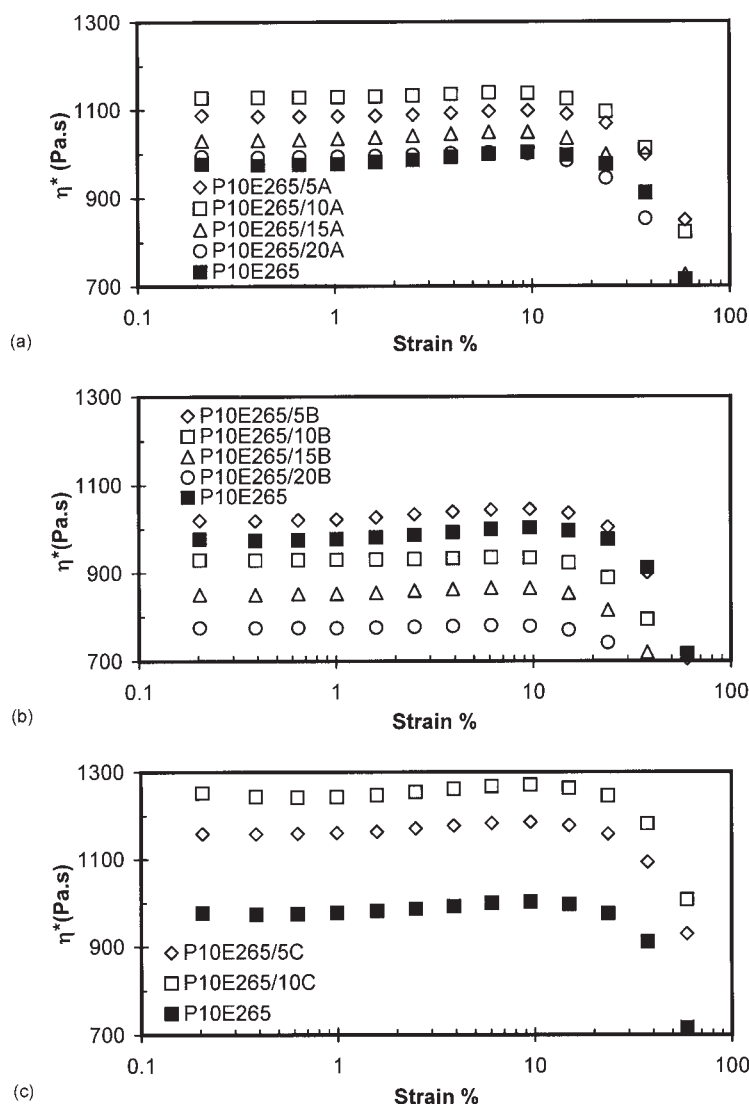


Figure 6 Dynamic strain sweep test for the blend P10E265 containing (a) compatibilizer A, (b) compatibilizer B, and (c) compatibilizer C.

the addition of compatibilizer up to 10 wt %, where it then decreases with further increases in the compatibilizer content. Only compatibilizer C shows a slight decrease in size from 10 to 15 wt % [Fig. 2(d) and (e)], but it does follow the general trend with the addition of 20 wt % compatibilizer, where the droplet size increases. The addition of compatibilizer has a positive effect on the blend systems. However, from the droplet size determined for the three compatibilized systems, the results indicate the possibility that excess amounts of compatibilizer were added to the blend systems. Given that the PS/EVA base composition was set at 90 wt % PS and 10 wt % EVA, addition of more than 10 wt % of compatibilizer could saturate the interface. Once this critical level or interfacial saturation is reached, the excess compatibilizer would likely become another dispersed phase (this will be discussed in detail in the section on the compatibilization model, below). This new dispersed

phase or droplets can account for the increase in the droplet size after 10 wt % of compatibilizer was added. The critical level can be inferred from the droplet size and impact properties of the blend systems. In the region of about 10 wt % of compatibilizer there was a significant decrease in droplet size, showing a substantial increase in impact strength. Subsequently, the increase in the impact strength is not as substantial, although it still increases. Further investigation into this region, to determine the critical level or interfacial saturation, would be beneficial. This critical level would probably give the optimum morphology and mechanical properties.

Compatibilization model

An empirical model for the compatibilization of immiscible polymer blends can be thought of as the

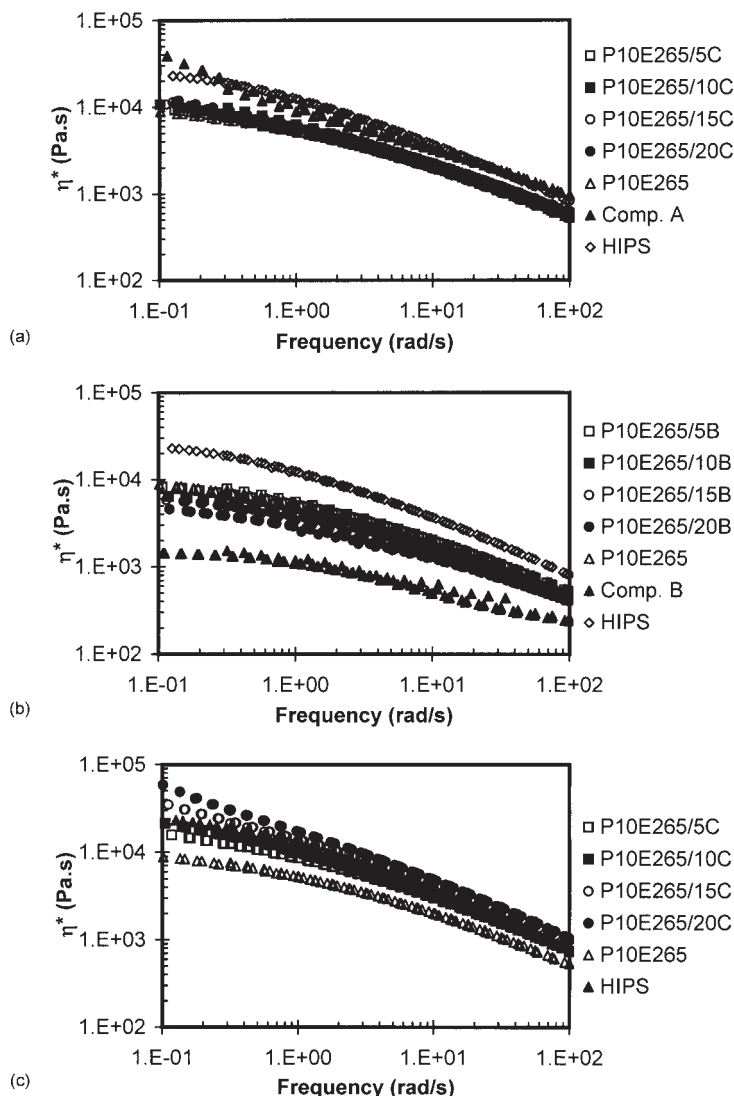


Figure 7 Dynamic viscosity master curve for the blend P10E265 containing (a) compatibilizer A, (b) compatibilizer B, and (c) compatibilizer C.

compatibilizer locating itself at the interface between the two immiscible phases of the polymer system. This happens only when an ideal compatibilizer is used, having two blocks miscible in both phases, respectively, although this does not always occur. Another possibility is that the compatibilizer does not locate itself at the interface at all and it forms another minor phase within the matrix of the major phase. In addition, a combination of these two possibilities can also occur. These possibilities are shown in Figure 4(a)–(e) in a simple pictorial representation. This model assumes that the amount of compatibilizer is at its critical concentration with no shortage or excess. When the compatibilizer content is below the critical level or the interfacial saturation point, it is likely that some EVA minor phase droplets could not be encapsulated by the compatibilizer. This possibility is summarized in Figure 4(f). Conversely, if the compatibilizer con-

centration exceeds the critical saturation concentration, it is likely that excess compatibilizer will precipitate as another phase, as shown in Figure 4(g).

DMA

Figure 5 demonstrates the effect of adding 5, 10, and 15 wt % of compatibilizers A, B, and C, respectively, to the PS/EVA blend. As can be seen from Figure 5(a) and (b), even though these blends contain three components, only two peaks are evident for blends loaded with 5–15 wt % of compatibilizers A and B. The transition peaks at subambient temperature are broader compared to those shown below in Figure 10, suggesting the possible overlapping of the glass-transition temperatures (T_g) of the compatibilizer and EVA. The absence of two peaks at subambient temperatures could be explained as follows: either (1) the T_g values

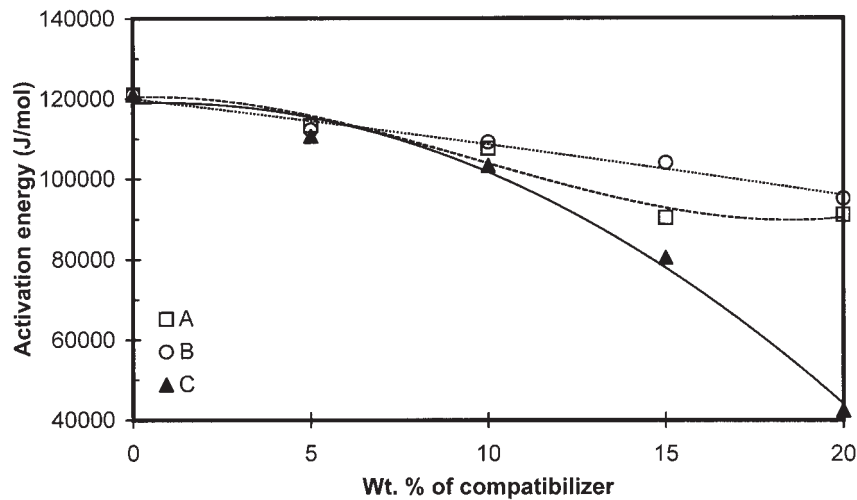


Figure 8 Effect of compatibilizers on activation energy.

of EVA and compatibilizers are too close ($<20^{\circ}\text{C}$) or (2) the proportion of EVA in the blend is too low.

Figure 5(c) shows that the blend with compatibilizer C exhibits three peaks. The third peak indicates the T_g for compatibilizer C at around -80°C . The signal becomes increasingly obvious when the amount of compatibilizer C is increased to 15 wt %. The results also show that the T_g of PS ($\sim 100^{\circ}\text{C}$) is not affected by the addition of compatibilizers, as indicated by the result for the blend of P10E265. The subambient peaks for the blends are summarized in Table IV. None of these peaks for the blends with compatibilizers A and B is close to EVA's T_g of -25.7°C . However, the second T_g of compatibilizer C yields a broad peak at a T_g near EVA.

Rheological properties

The melt-flow behavior of PS and EVA, coupled with three different types of compatibilizers, was studied

using a strain-controlled rheometer with a cone-and-plate geometry. Dynamic frequency sweep and steady rate sweep were carried out at 170, 180, 190, 200, and 210°C . The linear viscoelasticity was ensured by controlling the shear strain. The dynamic properties at different temperatures were corrected using the time-temperature superposition principle.

As shown in Figure 6, the flow curves from dynamic strain sweeps at 190°C indicate that addition of compatibilizer does not affect the linearity region of the polymer melt samples. Tests conducted at both extremes of temperature, ranging from 170 to 210°C , also show little change to the linearity region. Although different blend compositions have different dynamic viscosity values, the critical strain remains fairly constant. This could be explained by the fact that the three polymers (PS, EVA, and compatibilizer), when combined, do not interact. This was also investigated by the thermal analysis data that show that the samples

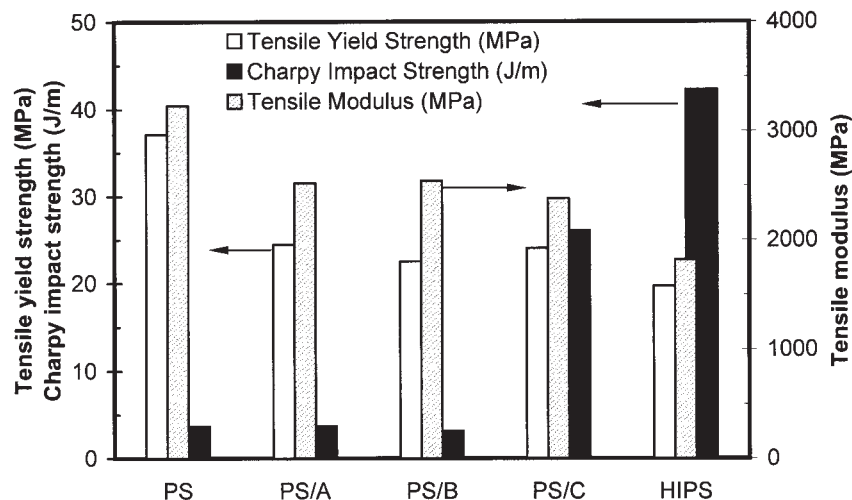


Figure 9 Effect of adding compatibilizers A, B, and C to PS on the mechanical properties.

TABLE V
Fracture Characterization and Average Particle Size of the PS/Compatibilizer Blends

Sample	Fracture characterization				Fracture type	Average particle size (μm)
	2 halves/ linked	Crack propagation type	Fracture surface texture	Crazing		
PS	2 halves	Slight branching	Smooth	No	Brittle	0.180
PS/A	2 halves	Straight	Smooth	No	Brittle	0.125
PS/B	2 halves	Straight	Slight roughness	No	Brittle	0.120
PS/C	2 halves	Very slight branching	Rough	No	Ductile-brittle	0.100

are immiscible. This seems to show that the critical strain for immiscible blends remained unchanged.

Figure 7 illustrates the dynamic complex viscosity for all samples exhibiting shear-thinning behavior. The viscosity of the polymer blend tends toward that of pure compatibilizer with increasing content of compatibilizer. Although the exact role of interfacial interactions between compatibilizer, PS, and EVA could not be determined, there is evidence that suggests their presence causes shifting of the dynamic viscosity plots. Of particular interest is compatibilizer C, whose samples show a large increase in the viscosity with increasing amount of compatibilizer. (Note: The response of pure compatibilizer C could not be obtained because it could not be melted.) The pure compatibilizer C seems to undergo degradation before melting. The samples containing compatibilizers A and C exhibit enhanced elastic properties with increasing compatibilizers. Compatibilizer C has a more pronounced effect.

The flow activation energy of a material is the measure of energy required to cause a flow in that material. Figure 8 shows that addition of compatibilizers tends to lower the activation energy of the material. Compatibilizer C had a much greater capacity of lowering activation energy, compared to that of the other compatibilizers. The blend loaded with 20 wt % com-

patibilizer C deviates substantially from the Arrhenius fit. This could be attributed to oxidation effect that occurred at the higher temperatures.

Effect of adding compatibilizer to PS

Mechanical properties

Figure 9 shows that the impact strength of PS with compatibilizers A and B decreases slightly, but a sharp increase is observed for compatibilizer C. This provides a strong indication that compatibilizer C itself is an effective impact modifier because of its elastomeric properties, which is supported by the results from the thermal studies, which show that the glass-transition temperature of compatibilizer C is lower than that of EVA.

The tensile properties show a general decrease in both the tensile yield strength and tensile modulus of the PS–compatibilizer blend compared to those of PS, which is expected for the inclusion of another dispersed phase. The morphological and fracture characterization also support the result that the impact strength for the blend of PS with compatibilizer C is the best of the three compatibilizers. As shown in Table V, these blends have a smaller average droplet size and a ductile–brittle type of fracture.

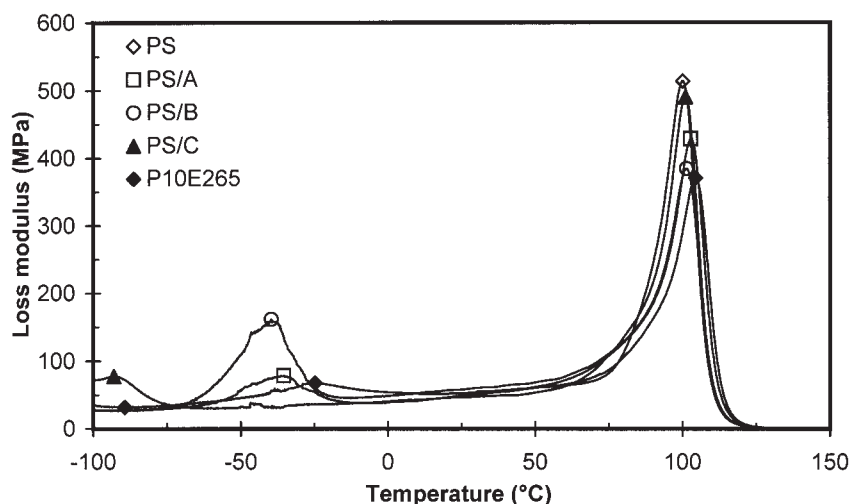


Figure 10 Effect of adding compatibilizers A, B, and C to PS. The comparison is made with PS and P10E265.

Basically, these results provide evidence that compatibilizer C does not function only as an interfacial agent. The additional dispersed phase, formed from the excess compatibilizer, serves to improve the impact characteristics of the PS/EVA blend. As seen from the results on the variation of compatibilizer C content, there is a sharp rise in the impact strength from 15 to 20 wt %, which could be explained by the excess compatibilizer serving as an additional impact modifier on the existing blend matrix. Figure 9 also shows that HIPS has much better impact strength than that of the three PS/compatibilizer blends. With the exception of PS loaded with 10 wt % compatibilizer C, the impact strength of the others actually becomes worse with addition of compatibilizer.

DMA

The effect of the compatibilizers on dynamic mechanical properties of PS is shown in Figure 10. Two distinct peaks may be observed in these blends, revealing that compatibilizers A, B, and C are immiscible with PS. The peaks of PS are shifted slightly to the right when blended with these compatibilizers. The T_g values of PS in the blends are 102.8, 101.1, and 100.6°C for 10 wt % of compatibilizers A, B, and C, respectively. T_g values of the compatibilizers A, B, and C were determined to be -35.4, -39.6, and -89.0°C, respectively. It is noted that compatibilizer C shows a small second peak at -46.7°C, attributed to the polybutadiene block in compatibilizer C. However, a similar observation could not be found in compatibilizer B, where the T_g of pure polyisoprene is in the range of -71 to -63°C.

Comparison was made with respect to the blend of P10E265 instead, as shown in Figure 10. The overlapping curves revealed that among EVA and compatibilizers A, B, and C, EVA had the greatest impact in reducing the loss modulus of PS. It was also observed that the T_g values of the compatibilizers are lower than that of EVA.

CONCLUSION

Dynamic mechanical analysis indicates that addition of compatibilizers to the PS/EVA blend (90:10 in weight) does not change the blend miscibility, given that the loss modulus curves of the blends exhibit distinct peaks of the respective components as their own T_g . However, broadening of the peak near the T_g of EVA was observed. This could be attributed to the

fact that T_g values of the compatibilizers are too close to that of EVA.

Increasing the amount of compatibilizer tended to shift the properties toward that particular compatibilizer. This was most probably a consequence of the additive effect of including the compatibilizer. The interfacial effect of the compatibilizer with PS and EVA could not be identified.

The morphology was successfully correlated with mechanical properties. It was observed that there was a reduction in droplet size, until the critical proportion or interfacial saturation was reached. There was a corresponding improvement in impact strength.

Although DMA revealed that there was no sign of miscibility in the compatibilized PS/EVA (90/10) blends, the mechanical properties of the blend incorporating 15 wt % of compatibilizer C were comparable to those of the commercially available HIPS, as summarized in Table I.

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