

Determination of Optimum Compatibilizer (SMA) Concentration for PBT/ABS (70/30) Blend Using Tensile Strength Data

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ABSTRACT: Poly(butylene terephthalate) (PBT), a thermoplastic polyester, was melt blended with acrylonitrile–butadiene–styrene (ABS) terpolymer using styrene–maleic anhydride (SMA) as the compatibilizer. The PBT : ABS ratio was fixed at 70 : 30 by weight and weight percent (wt %) of SMA was varied as 2.5, 5, and 7.5. The effect of variation of the SMA percent in the blend was studied by calculating and comparing the theoretical tensile strength values with the experimental ones. The adhesive strength (σ) and the interaction parameter (I) were also determined. © 1997 John Wiley & Sons, Inc. *J Appl Polym Sci* **64**: 1485–1487, 1997

Key words: melt blending; compatibilizer; additivity principle; interaction parameter; adhesive strength

INTRODUCTION

The directive force for development of a polymer blend is generally a combination of economy of the blend and its performance toward application. Miscible blends in general follow the simple “rule of mixtures,” resulting in property additivity. The property P of a miscible blend is a function of composition (W) and some interaction between the components represented by an interaction parameter I . The relationship between P , W , and I is given by the following well-known expression:

$$P = P_A W_A + P_B W_B + I W_A W_B \quad (1)$$

where A and B refer to the two blend components. The interaction parameter I may either be positive or negative.

Melt blending of two or more polymers that are

incompatible generally results in a heterogeneous product that has a relatively weak interfacial adhesion and accordingly results in relatively poor mechanical performance. Physical and chemical interaction across the phase boundaries are known to control the overall performance of polymer blends. Strong interactions result in good adhesion and efficient stress transfer from the continuous to the dispersed polymer phase in the blend.

To make incompatible blends compatible, the use of compatibilizers are utilized. They act as the third component, which may be a block or graft copolymer in nature.^{1–4}

In the present work an attempt was made to compatibilize the poly(butylene terephthalate)/acrylonitrile–butadiene–styrene (PBT/ABS) blend by adding the graft copolymer styrene–maleic anhydride (SMA) as the compatibilizer.

Because the solubility parameters (δ) of PBT (10.7 cal^{1/2} cm^{-3/2}) and ABS (9.43 cal^{1/2} cm^{-3/2}) differ so much, they are an incompatible blend. SMA has a δ value of 10.01 cal^{-1/2} cm^{-3/2}, which

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is intermediate between these two; therefore, it can act as a compatibilizer. The solubility parameters were determined by using the molar-attraction constants, E , and putting them in eq. (2).

$$\partial = \frac{\rho \sum E}{M} \quad (2)$$

where values of E are summed over the structural configuration of the repeating unit in the polymer chain, with repeat molecular weight, M , and density, ρ .⁵

During melt blending, SMA reacts with the terminal —OH group of PBT, forming a graft copolymer (SMA-*g*-PBT).⁶ Similarly, SMA has good compatibility with ABS due to the presence of structurally similar styrene units in the polymer backbone.

EXPERIMENTAL

Materials

PBT, under the trade name Arnite T-06, was obtained from Cenka Plastics Ltd. (India). ABS terpolymer (trade name of Polylac-100 GP-1) was obtained from Polychem (India). SMA, under the trade name Dylark-232, was obtained from ARCO Chemical Company.

The blends of 70/30 wt % of PBT/ABS with 2.5, 5, and 7.5 wt % SMA as compatibilizer were prepared by melt mixing using a single screw extruder (Windsor SX-30) of $L/D = 30$. The individual polymers were first dried in a vacuum oven for 6 h at 100°C and were then quickly fed into the hopper of the extruder that had been preheated at 240°C. After the chamber was completely full and the polymer had fluxed, the lid was closed to minimize moisture absorption. The temperature in the compression zone was 250°C and at the die end was 255°C. The molten extrudates were quickly immersed in water bath, thus quenching them at room temperature. The blends obtained were collected as strands and were chopped into granules in a granulator and finally dried in a vacuum oven at 80°C for 24 h. Screw speed was maintained at 20 rpm throughout the process.

The dumbbell-shaped tensile test specimens were injection molded using a Windsor-SP-I screw-type injection molding machine. The tensile strengths were measured using an Instron-4301 Universal testing machine.

RESULTS AND DISCUSSION

The effect of the mismatch of poorly adhering components at the interface was analyzed with the help of a simple model developed by Nolley and coworkers.⁷ It was assumed that the adhesive strength of a bond formed in the melt between polymers i and j in tension is σ_{ij} . For the random case, the adhesion resulting from i to j contact would be $\sigma_{ij}f_i f_j$, where f_i and f_j are surface fractions of the components i and j . The total tensile strength (TS) at the interfaces is then the overall sum of all positive types of contacts:

$$\text{TS} = \sum_{ij} \sigma_{ij} f_i f_j \quad (3)$$

For a binary blend system, we assume that the surface area fraction is equal to bulk volume fraction, $f_i = \phi_i$ and $f_j = \phi_j$. Because $\sigma_{ij} = \sigma_{ji}$, hence eq. (3) reduces to

$$\text{TS} = \sigma_{ii}\phi_i^2 + \sigma_{jj}\phi_j^2 + 2\sigma_{ij}\phi_i\phi_j \quad (4)$$

where σ_{ii} and σ_{jj} refer to the adhesive strength of the pure components themselves. In the limit of poor adhesion of components i and j , that is, for the PBT/ABS blend $\sigma_{ij} = 0$, eq. (4) reduces to

$$\text{TS} = \sigma_{ii}\phi_i^2 + \sigma_{jj}\phi_j^2 \quad (5)$$

with $\phi_i + \phi_j = 1$.

Because the volume fraction of the third component, the compatibilizer (ϕ_k), was very low compared to ϕ_i and ϕ_j , the equation derived for the binary system was used to calculate theoretically expected TS values of compatibilized blends, assuming $\sigma_{ij} = 0$. But the results were not in good agreement with experimental values (Table I). The calculated TS values of all compositions containing SMA lie below those of the experimental values, proving $\sigma_{ij} \neq 0$ when compatibilizer is used.

Using eq. (4) and experimental σ_{ii} and σ_{jj} values, σ_{ij} values were calculated for the blends with and without compatibilizer and are shown in Table I. The value is highest for the system containing 5% SMA. For the 7.5% SMA blend, the σ_{ij} value is slightly lower.

The interaction parameter I values calculated from eq. (1) also support this result. As expected, I is positive for systems with 5 and 7.5% SMA, with a higher value for the 5% SMA blend. Thus, it can be stated that on addition of SMA the I

Table I Experimental and Theoretical Tensile Strengths, Interaction Parameters, and Adhesive Strengths of PBT/ABS/SMA Blends

PBT/ABS (70/30) Blend (wt %)	SMA (wt %)	Tensile Strength			Interaction Parameter (I)	Adhesive Strength (σ_{ij})
		Experimental (MPa)	Additivity (MPa)	Nolley (MPa)		
100.0	0	24.8	43.08	26.86	-0.06	0.62
97.5	2.5	37.5	42.12	24.71	-1.67	2.32
95.0	5.0	44.0	41.15	24.93	15.32	42.74
92.5	7.5	41.0	40.19	25.26	4.66	35.86

value becomes less negative, indicating better interfacial adhesion in the presence of compatibilizer.

The TS calculated by using the additivity principle (Table I) also support the above results. Comparing these values with the experimental ones, it is clearly observed that blends having 5 and 7.5% SMA show positive derivation from additivity values. The deviation is higher in the 5% SMA blend compared to the 7.5% blend.

The positive deviation of the TS values from additivity values on addition of SMA can be attributed to the better interaction between the two polymers in the presence of the compatibilizer, leading to an increase in interfacial tension. Heikens and coworkers^{8,9} also reported a similar increase in yield strength and TS of polystyrene and low density polyethylene blends on addition of a graft copolymer made from the two polymer components of the blend.

Willis and Favis⁴ reported that at higher compatibilizer concentration excess molecules may concentrate at the interface and lead to flocculation, arising due to strong interparticle interaction. This effect can deteriorate the blend properties. Perhaps this is the reason for the lower tensile values at 7.5% SMA blends compared to 5% SMA blends. At still lower concentrations (2.5% SMA), lower values of σ_{ij} are probably due to the fact that the amount of SMA between the phases is not adequate to facilitate adhesion. Thus, to achieve uniform dispersion and improve adhesion, 5% compatibilizer content was found to be optimum in this case and an excess was not necessary.

CONCLUSION

Immiscible PBT/ABS blends can be compatibilized using SMA as a compatibilizer. Comparing the tensile values obtained experimentally for the 70/30 (PBT/ABS) blends containing 2.5, 5, and 7.5 wt % of SMA with those calculated using additivity principle, Nolley's model, and the interaction parameter and adhesion strength values, it is clear that 5% SMA is the optimum amount needed for best compatibilization of PBT/ABS blend.

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