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IMPACT PROPERTIES OF THE POLYMER BLEND OF POLYPROPYLENE AND THERMOPLASTIC ELASTOMER

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ABSTRACT

Improvement of the impact strength with little sacrifice of the modulus for polypropylene (PP) blends was investigated by blending PP with isoprene-styrene block copolymers (ISR-A, B, C, and D) and ethylene-propylene random copolymer as thermoplastic elastomers. Neither of the blends whose flexural modulus ranged from 1530 MPa, that of PP, to 1400 MPa showed a significant improvement of the notched Izod impact strength (< 47 J/m) as compared with that of PP (32 J/m). The blend of PP and the isoprene-styrene diblock copolymer with the weight percent of the feed styrene of 30 wt% (ISR-A) (weight ratio of PP/ISR-A, 80/20 and 70/30) had a very high impact strength (83 and 100 J/m). The flexural moduli of the blends were 1280 and 1070 MPa, respectively. From the SEM micrographs, it appeared that the PP/ISR-A (70/30) blend is a microphase-separated sytem with a good dispersion of the elastomer. In the dynamic viscoelastic curves of PP/ISR (70/30) blends, the height of the tan δ peak at around -50°C related to the glass transition of polyisoprene segment was the highest in the PP/ISR-A blend, in agreement with the high impact strength.

INTRODUCTION

Easy processing and low cost, in addition to the originally superior properties of polypropylene (PP), stimulated heavy investment in the PP industry all over the world. Low temperature brittleness is a major disadvantage of the PP to the extended application. Polymer blends of the PP and various elastomers such as ethylene-propylene random copolymer (EPR), ethylene-propylene-diene terpolymer (EPDM), styrene-butadiene-styrene block copolymer (SBS) etc. have been extensively investigated with a view to the improvement of impact properties [1-6]. High modulus, in addition to high impact strength, is also needed for the materials such as the fenders of automobiles [7, 8]. Fundamental research, such as crystallization behavior, morphologies and reological studies on the PP blends have been actively performed in connection with the impact properties [9-13]. However, very few systematic studies on the relationship between impact strength and modulus in the PP blends are found in the paper. Here we report on this relationship in the blends of PP and thermoplastic elastomers such as isoprene-styrene block copolymers (ISR) and ethylene-propylene random copolymer (EPR).

EXPERIMENTAL

Materials

The materials used were PP homopolymer (MA3, number-average molecular weight 48,000, weight-average molecular weight 270,000, Japan Polychem Co. Ltd.), ethylene-propylene random copolymer (EPR-07, the weight ratio of the feed ethylene/propylene = 73/27, Kuraray Co. Ltd.) and isoprene-styrene block copolymers (ISR-A, B, C, D, Table 1, Kuraray Co. Ltd.).

Blending and Injection Molding

Blending was performed using a Laboplasto-Mill with a twin rotary mixer (Toyo Seiko Co. Ltd., Japan). The molten mixing of the materials was carried out at 210°C, the rotary speed was 50 rpm and the mixing time was 5 minutes. All the polymers were dried at 100-120°C for 5 hours prior to blending. Dumb-bell specimens (width 5 mm x thickness 2 mm x length of parallel part 32 mm x total length 72 mm) were molded using a desk injection molding machine (Little-Ace I type, Tsubako Co. Ltd., Japan). The cylinder temperature and molding temperature during the injection molding were 210°C and 60°C, respectively.

TABLE 1. Compositional Date of Isoprene-Styrene Block Copolymers

	ISR-A	ISR-B	ISR-C	ISR-D
Styrene content (wt.-%)[a]	30	30	30	60
Specific gravity	0.92	0.92	0.92	0.97
Block type	Di	Tri	Tri	Tri
MFR (g/10 min)[b]	0.1	70	2.4	0.4

[a] The weight percent of the feed styrene to the total monomers used in the synthesis of the block copolymer.

[b] Measurement conditions: 230°C, load 2.16 kg

Measurements

The morphology of the blends was observed by scanning electron microscopy (SEM), using a JSM-840 machine (Japan Electron Co. Ltd.). All samples were fractured after immersion of the dumb-bell specimen in liquid nitrogen for about 5 minutes. Dynamic viscoelastic measurements were performed on a Rheolograph Solid (Tokyo Seiki Co. Ltd.) with a chuck distance of 20 mm, a frequency of 110 Hz and a heating rate of 2°C/min. Notched Izod impact tests were carried out at ambient conditions on a Digital Impact Testing Machine DG-IB (TokyoSeiki Co. Ltd.) according to the standard method for testing Izod impact properties of rigid plastics (JIS K7111 (1989)). Flexural properties were examined at ambient conditions using an Autograph AGS-500C (Shimazu Co.) based on the standard method for testing flexural properties of rigid plastics (JIS K7203 (1982)). Span length was 30 mm and the testing speed was 10 mm/min.

RESULTS AND DISCUSSION

Izod Impact Strength, SEM Morphologies and Dynamic Viscoelastic Behavior of the Blends

Isoprene-styrene block copolymers (ISR-A, B, C, D) shown in Table 1 and ethylene-propylene random copolymer (EPR-07) were used as thermoplastic elasto-

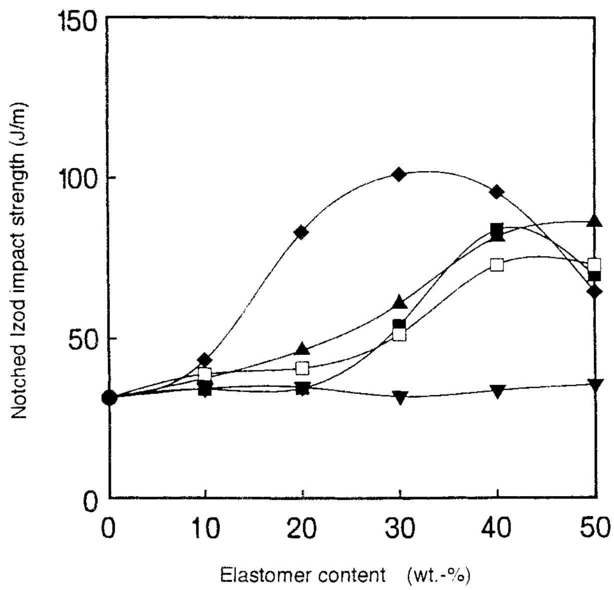

Figure 1. Relationship between the elastomer content and the notched Izod impact strength of the blends:(●) PP, (◆) PP/ISR-A, (■) PP/ISR-B, (▲) PP/ISR-C, (▼) PP/ISR-D, (□) PP/EPR-07.

mers for blending with PP. Figure 1 shows the notched Izod impact strength of the blends of PP and the elastomers. The Izod impact strength increased by the addition of the elastomers except for ISR-D with high polystyrene content. The maximum impact strength of the PP/ISR-A (100 J/m, ISR-A content 30 wt%) was higher than those of the PP/ISR-B, ISR-C, and EPR blends (75-85 J/m, elastomer content 40-50 wt%). The SEM micrographs of the fracture surface of the PP/EPR (70/30) and PP/ISR-A (70/30) blends are shown in Figure 2. Both the blends appear in the phase-separated system. Particle size of the elastomer is smaller in the PP/ISR-A blend (ca. 0.5 μ) than in the PP/EPR blend. Also, the dispersion of the elastomer is very good in the PP/ISR-A blend. No information on the different impact strength among the PP/ISR-A, B, C and D blends was obtained from the SEM micrographs because of the similarity of the micrographs of the blends. Figure 3 shows the dynamic viscoelastic curves of the PP/elastomer blends (70/30). The loss factor (tan δ) peaks related to the glass transition of polypropylene and polyisoprene segments were observed at around 10°C and -50°C for the PP/ISR blends, respectively. The loss factor peak at around -50°C for the PP/EPR blend is attributed to the presence

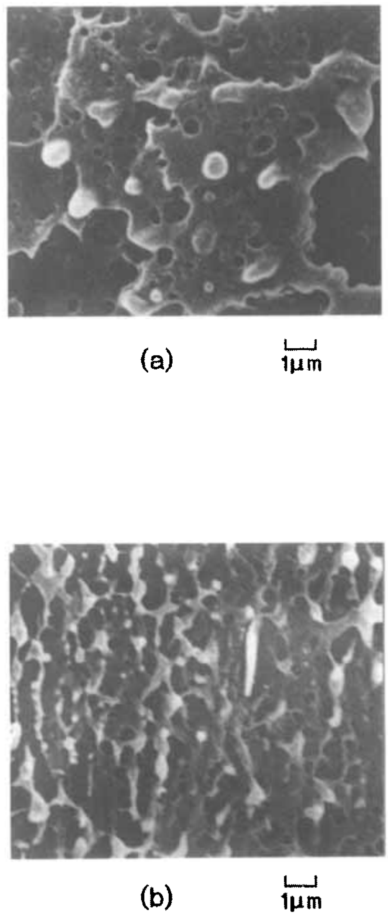

Figure 2. SEM micrographs of the fracture surfaces of (a) the PP/EPR-07 (70/30) blend and (b) the PP/ISR-A (70/30) blend.

of ethylene-propylene rubber. The content of polyisoprene segment of ISR-A, B and C are thought to be close to each other, judging from the same weight percent of the feed styrene. However, the latter peak height of PP/ISR-A blend was the highest, indicating that the content of amorphous polyisoprene segment of PP/ISR-A is the largest in agreement with the result of the Izod impact test. In addition, the higher molecular weight of ISR-A, as compared with ISR-B, C and D as indicated from the difference of melt flow rate (MFR), is thought to contribute to the higher impact strength of the PP/ISR-A blend. Although the highest impact strength was

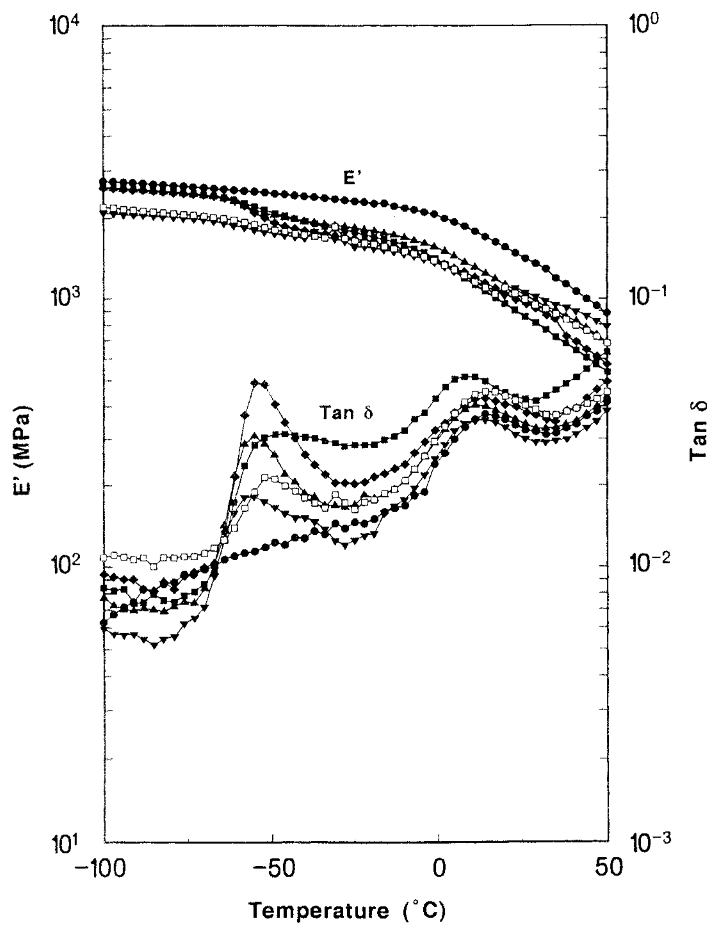

Figure 3. Dynamic viscoelastic curves of PP and the PP/elastomer blends: (●) PP, (◆) PP/ISR-A (70/30), (■) PP/ISR-B (70/30), (▲) PP/ISR-C (70/30), (▼) PP/ISR-D(70/30), (□) PP/EPR-07(70/30).

obtained in the blend of PP and ISR-A having diblock structure, it is not clear how the difference of the block type (di- or triblock) contributes to the impact strength in this study.

Relationship between Impact Strength and Flexural Properties of the Blends

The flexural strength and modulus of the PP/elastomer blends are shown in Figures 4 and 5, respectively. The flexural strength and modulus decreased with increasing content of the isoprene-styrene copolymers (ISR-A, B, C, and D). The

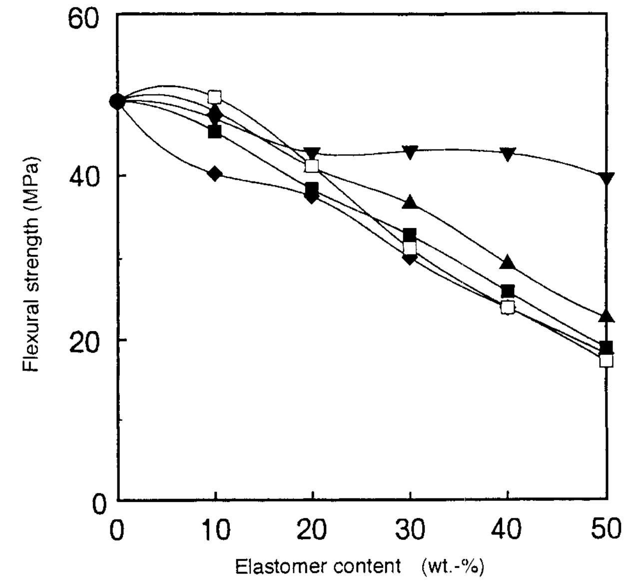

Figure 4. Relationship between the elastomer content and the flexural strength of the blends: (●) PP, (◆) PP/ISR-A, (■) PP/ISR-B, (▲) PP/ISR-C, (▼) PP/ISR-D, (□) PP/EPR-07.

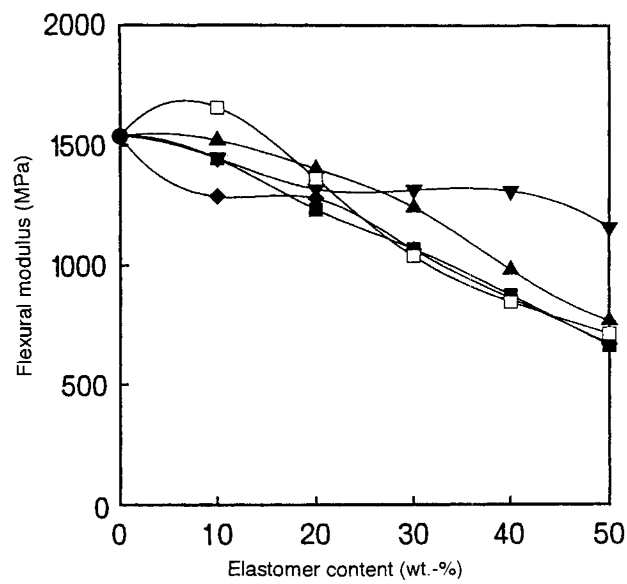

Figure 5. Relationship between the elastomer content and the flexural modulus of the blends: (●) PP, (◆) PP/ISR-A, (■) PP/ISR-B, (▲) PP/ISR-C, (▼) PP/ISR-D, (□) PP/EPR-07.

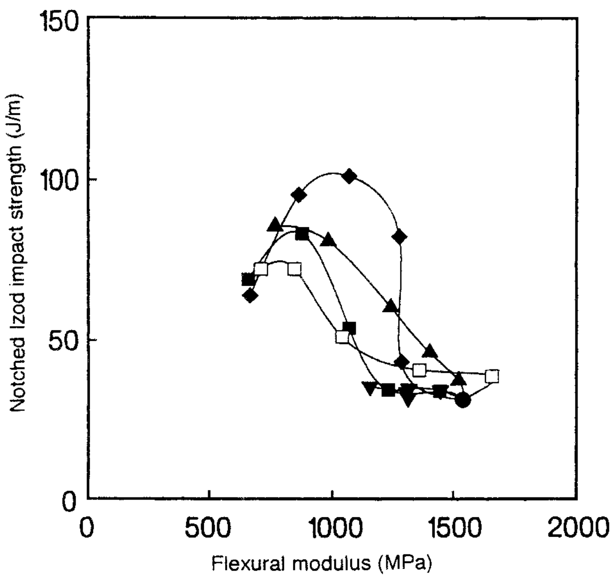

Figure 6. Relationship between the flexural modulus and the notched Izod impact strength of the blends: (●) PP, (◆) PP/ISR-A, (■) PP/ISR-B, (▲) PP/ISR-C, (▼) PP/ISR-D, (□) PP/EPR-07.

decreases of the strength and modulus were larger in ISR-A, B and C than in ISR-D with higher polystyrene content. Although the strength and modulus of the PP/EPR blend slightly increased at the EPR content of 10 wt% as compared with those of the PP, those values with the addition of EPR 20 wt% or above decreased to the same extent as the PP/ISR blends. Figure 6 shows the relationship between the flexural modulus and the notched Izod impact strength of the blends. In the range of the flexural modulus of 1530 MPa, that of PP, to 1400 MPa, neither of the blends showed a significant improvement of the Izod impact strength (< 47 J/m) as compared with that of PP (32 J/m). The PP/ISR-A blends (80/20 and 70/30) with the flexural modulus of 1280 and 1070 MPa had a very high impact strength (83 and 100 J/m), respectively.

CONCLUSION

The relationship between the notched Izod impact strength and the flexural modulus of the blends of PP with isoprene-styrene block copolymers (ISR-A, B, C, and D) and EPR as thermoplastic elastomers were investigated. As a result, the PP/ISR-A (80/20 and 70/30) blend had a very high impact strength (83 and 100 J/m) with little lowering of the flexural modulus (1280 and 1070 MPa) as compared with those of PP (32 J/m, 1530 MPa). The PP/ISR-A blend is thought to be the promising material having superior balance of impact strength and modulus.

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