

Effect of Styrene-Butadiene-Styrene Addition on Polystyrene/High-Density Polyethylene Blends

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ABSTRACT: In order to prepare an ideal mixture, the physical and chemical properties of the constituent polymers must be known in detail. Thus, selection of the polymers that will constitute the mixture and a thorough study of the mixing methods and the economic factors become important. A rigid plastic is toughened by dispersing a small amount of rubbery material (generally 5–20%) in the rigid plastic matrix. Such a mixture of plastics is characterized by its impact resistance. Among thermoplastics toughened in this way are polystyrene (PS), poly(vinyl chloride), poly(methyl methacrylate), polypropylene, polycarbonate, and nylons, and recently thermoset resins such as epoxies, unsaturated polyester resins, and polyamids. In this study PS and high-density polyethylene polymers were mixed in various ratios. In order to increase the compatibility of the mixtures, 5, 7.5, and 10% SBS copolymer was also added. The mixing operation was conducted by using a twin-screw extruder. The morphology and the compatibility of the mixtures were examined by using SEM and DSC techniques. Furthermore, the elastic modulus, yield and tensile strengths, percent elongation, Izod impact resistance, hardness, and melt flow index values of the polymer alloys of various ratios were determined. © 2002 John Wiley & Sons, Inc. *J Appl Polym Sci* 83: 2967–2975, 2002; DOI 10.1002/app.2325

Key words: copolymer; polystyrene; mixtures; extrusion; microstructure

INTRODUCTION

Polymer alloys and blends are of great interest academically and technologically. In many cases, a balance between the hardness and toughness is desired. The hardness of many synthesized polymers is characterized by brittleness and crack propagation upon impact. Therefore, improvement of the toughness was the subject of academic and technological investigations.^{1,2} The principal condition for a satisfactory result in

toughening plastics with rubber is the achievement of good adhesion to plastic materials via improved solubility of the rubber phase in the plastic matrix. There is a limited selection of rubbers that result in such strong adhesion to a rigid polymer.^{3,4}

There are several studies reporting the use of styrene-butadiene-styrene (SBS), styrene-butadiene (SB), and styrene-ethylene-butadiene-styrene (SEBS) type block copolymers in toughening of polystyrene (PS).^{5–9} It was also shown that mixing such copolymers with high-density polymers is more effective. Schwarz et al.¹⁰ showed that the addition of SEBS, SEB, and ethylene-propylene-diene monomer (EPDM) copolymers to polyethylene (PE)/polyester carbonate blends and

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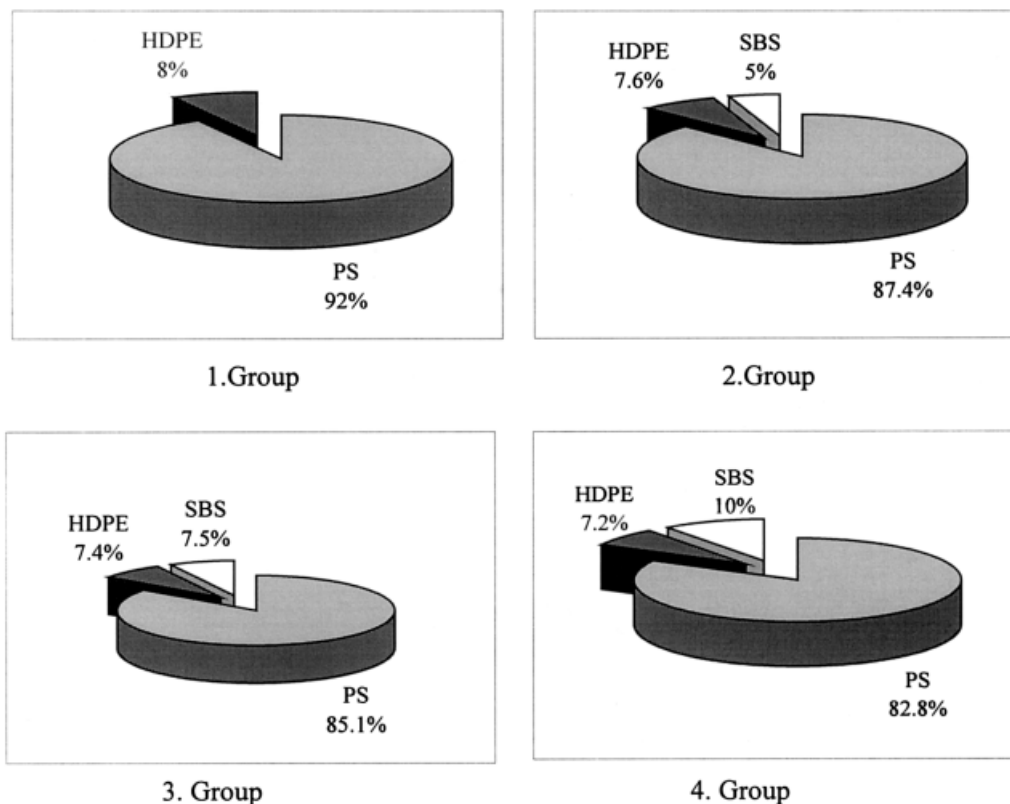


Figure 1 Pie charts showing the nominal compositions of the PS/HDPE/SBS alloys studied.

to PS decreased the elasticity modulus and yield strength of the blends while increasing the percent elongation and impact strength.

Furthermore, Shaw and Singh^{11,12} reported that the addition of EPDM led to a considerable improvement in the impact strength of PS while adversely affecting its tensile strength. Yang et al.^{13,14} also studied copolymer addition to polymer blends and reported that 5% styrene-ethylene-propylene and SEBS addition to a linear low-density PE/PS blend improved the compatibility significantly. In polymer alloys composed of PS/high-density PE (HDPE)/SBS, changing the ratio of each constituent or processing conditions would affect the mechanical properties. Therefore, this study was based on changing the ratio of SBS in this system.

EXPERIMENTAL

Materials

Four different polymer alloys were prepared by changing the ratio of SBS in the PS/HDPE/SBS

system by maintaining the ratio of HDPE at nominally 7.5% as shown in Figure 1.

The alloy constituents used in this study were of industrial origin; PS had a melt flow index (MFI) value of 10.0–14.0 g/10 min (190°C and 2160 g) and a Vicat softening point of 90°C; HDPE had a melting point of 135°C and a MFI value of 4.4–6.5 g/10 min (190°C and 2160 g); and SBS had a MFI smaller than 1 g/10 min. MFI value (200°C and 5000 g). Granular samples of the polymer blends were prepared by using a twin-screw extruder at 170 rpm and a temperature range of 130–170°C under 21-bar pressure. The granular material was then used to prepare tensile test specimens with an injec-

Table I Process Parameters Used in Injection Press Molding of Tensile Test Specimens

Parameter	Value
Injection temperature	185°C
Injection pressure	40 bar
Dwell time in mold	10 s

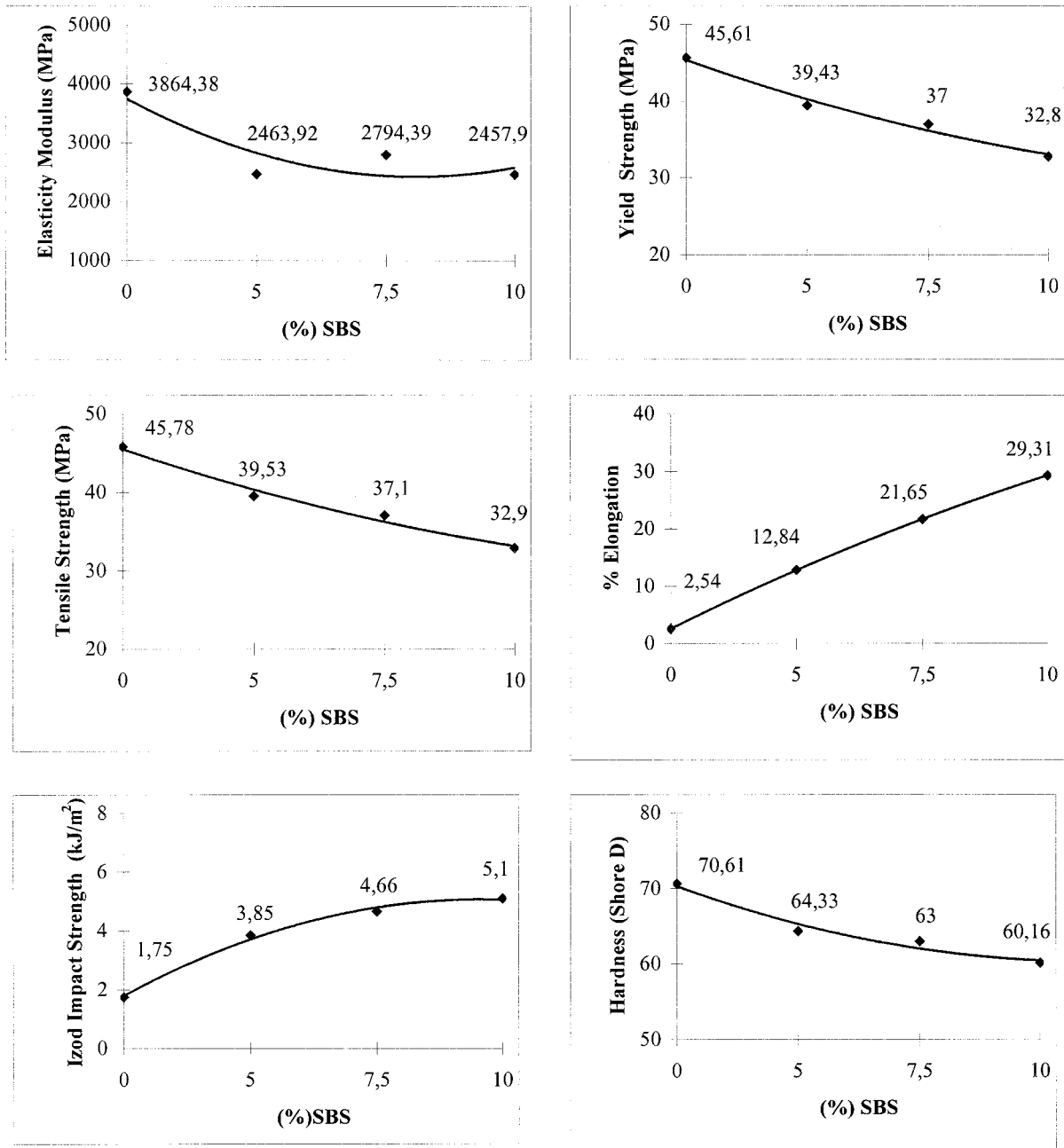


Figure 2 The changes in the mechanical properties of PS/HDPE/SBS alloys with the addition of SBS.

tion press. Table I shows the conditions used in this process.

Testing and Characterization of Polymer Alloys

Tensile test samples were prepared in accordance with the ISO 294 standard using an NMC brand injection molding machine. Tensile and impact tests were conducted according to ISO 527.2 at a

crosshead speed of 50 mm/min and ISO 180 standards, respectively, by using Zwick brand machines. The MFI values were obtained according to ASTM D1238 using Ceast test equipment. The DSC studies were undertaken by using a Setaram DSC 131 for the group 1 and 2 samples and a Universal V2-6DTA for the group 3 and 4 samples. The SEM examinations were made with a

Table II MFI Values of PS/HDPE/SBS Polymer Alloys

Type	MFI (g/10 min)
Group 1	10.26
Group 2	7.79
Group 3	6.80
Group 4	6.38

MFI, melt flow index determined at 200°C and with 5000 g of sample.

Jeol JSM-T330 operated at 15 kV after coating the samples with gold for conductivity.

RESULTS

Mechanical Properties

Figure 2 shows the elasticity modulus, yield and tensile strengths, percent elongation, impact strength, and hardness values of PS/HDPE alloys containing SBS in various ratios. As can be seen in this figure, up to a 10% SBS addition the elasticity modulus, yield and tensile strengths, and hardness of the polymer alloy decreased while the percent elongation and impact strength increased.

Thermal Properties

MFI Values

The MFI values of the four groups of polymer alloys having various PS/HDPE/SBS ratios are given in Table II. These values appeared to decrease with increasing SBS ratio. The highest MFI value of 10.26 g/10 min was achieved with the blend containing a PS with a high MFI, HDPE with a low MFI, and no SBS.

DSC Observations

During the heating of the PS/HDPE blend the glass-transition temperature of the PS was observed at 102.4°C. Upon further heating the melting temperature of HDPE was determined to be 132.11°C. The crystallization peak for HDPE was detected at 98°C during the controlled cooling of the blend. The addition of SBS did not appear to alter the heating and cooling curves considerably. The temperature data obtained from the DSC work are given in Table III. The DSC curves are presented in Figure 3.

Morphological Characteristics

The fracture surfaces of the polymer alloys were examined via SEM in an attempt to correlate the mechanical properties to the microstructural characteristics. Figure 4 shows the micrographs taken from the fracture surfaces of the four polymer alloys studied. It was observed that in the absence of SBS the present phases in the blend did not appear to adhere well and behaved as individual blocks. Although the adhesion seemed to be enhanced as the SBS was added at 5 and 7.5%, the level of homogeneity in the dispersion of phases still appeared to be insufficient. Upon reaching 10% SBS addition the adhesion and distribution of the present phases were considerably enhanced (Fig. 4).

CONCLUSION

It was shown that increasing the addition of SBS copolymer to the PS/HDPE blend from 5 to 10% enhanced the percent elongation and impact strength of the alloy while the yield and tensile strength, elasticity modulus, and hardness deteriorated (Fig. 2). This result was in accord with other findings in the literature.^{10,13,14} The DSC and SEM examinations in this study indicated that SBS is a good addition for PS/HDPE polymer blends in terms of compatibility. The DSC observations showed that the addition of SBS had no significant effect on the heating or cooling curves. The SEM examination revealed that a 10% SBS

Table III Temperature Data Obtained from DSC for PS/HDPE/SBS Polymer Alloys

Group	Temp. Type (°C)	PS	HDPE
1	T_g	102.40	—
	T_m	—	132.11
	T_c	—	98.00
2	T_g	102.20	—
	T_m	—	131.91
	T_c	—	105.50
3	T_g	101.16	—
	T_m	—	128.43
4	T_g	102.23	—
	T_m	—	129.05

T_g , T_m , and T_c , glass-transition, melting, and crystallization temperatures, respectively.

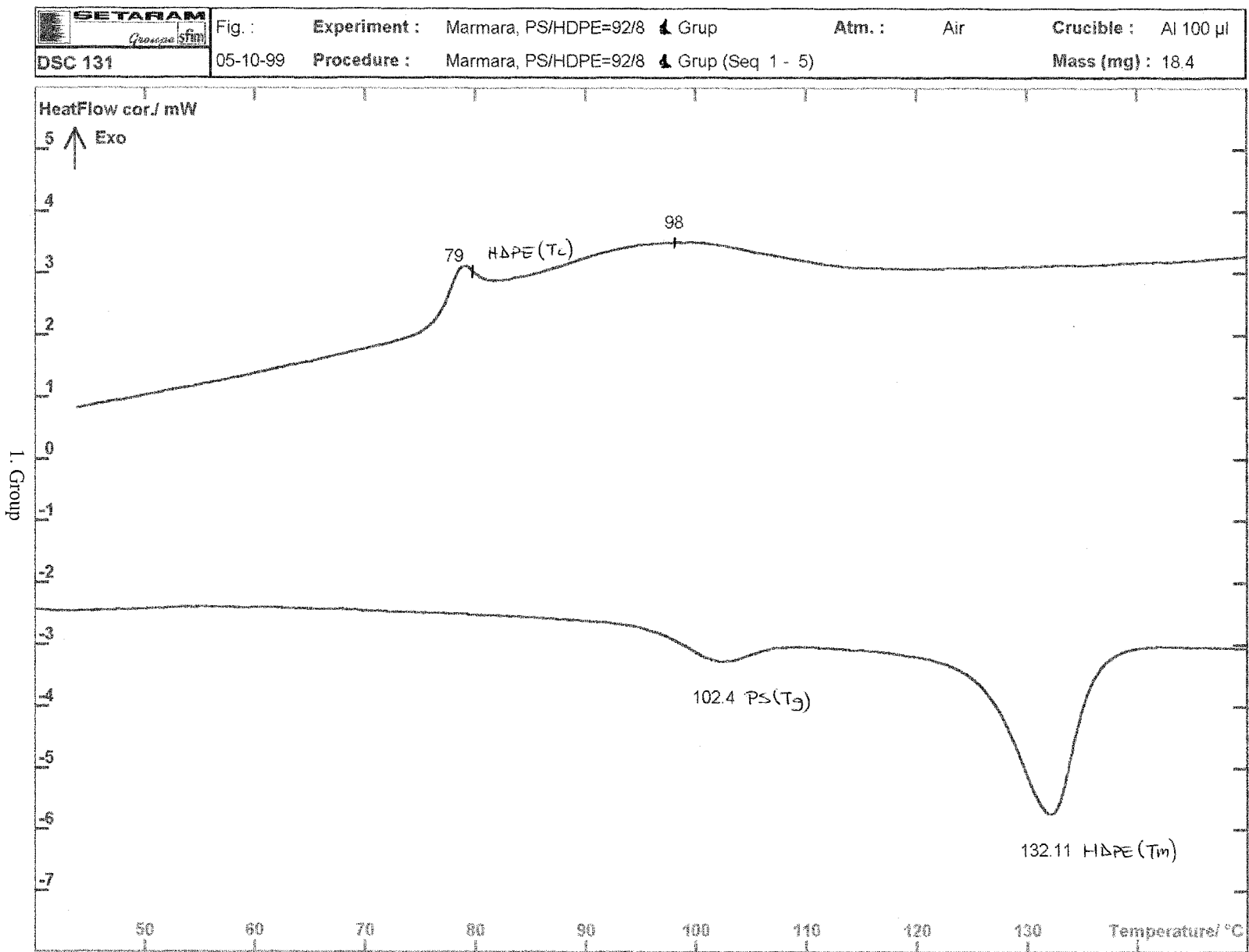


Figure 3 The DSC curves for PS/HDPE/SBS polymer alloys.

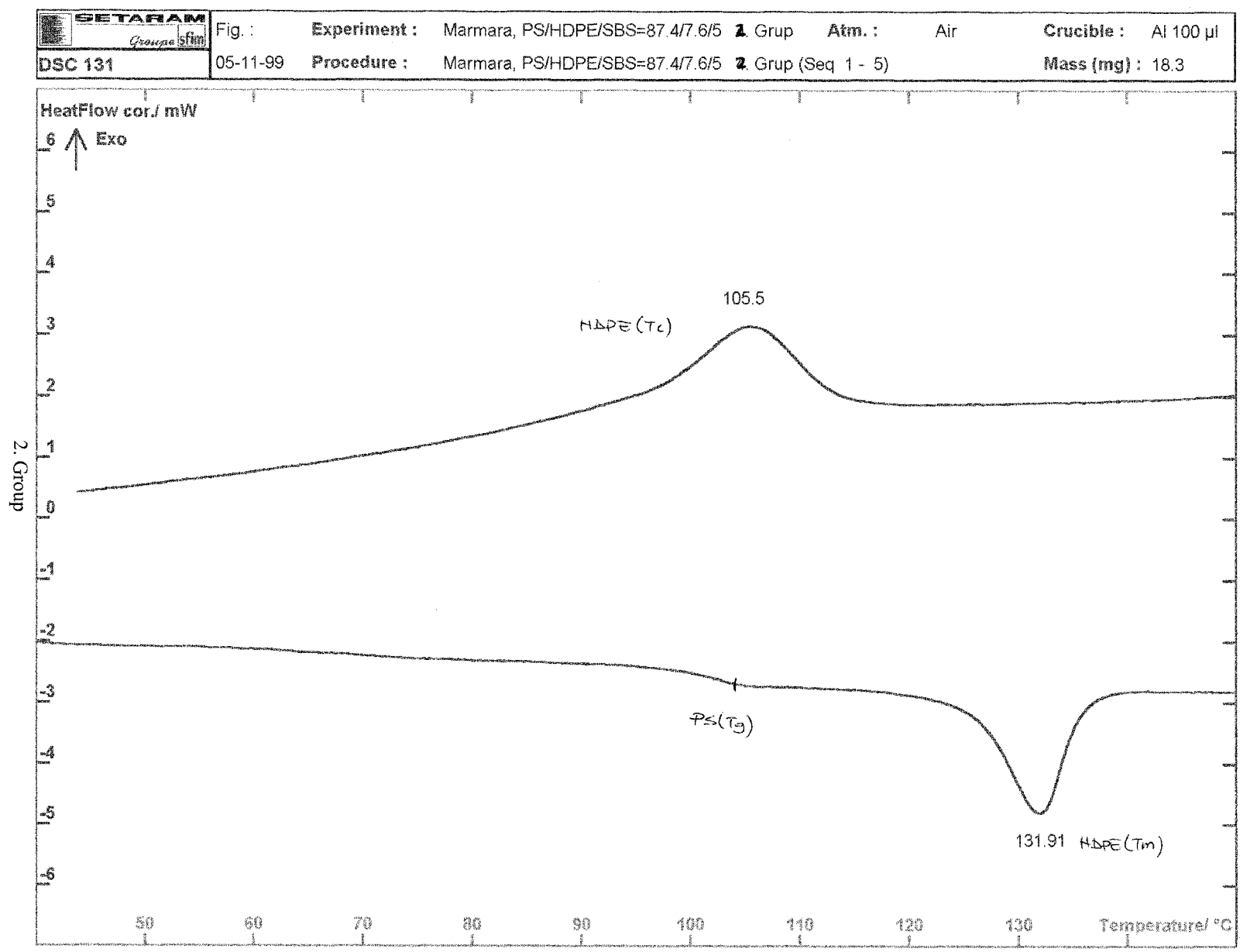


Figure 3 (Continued from the previous page)

Sample: numune 2
Size: 16.2000 mg

DSC

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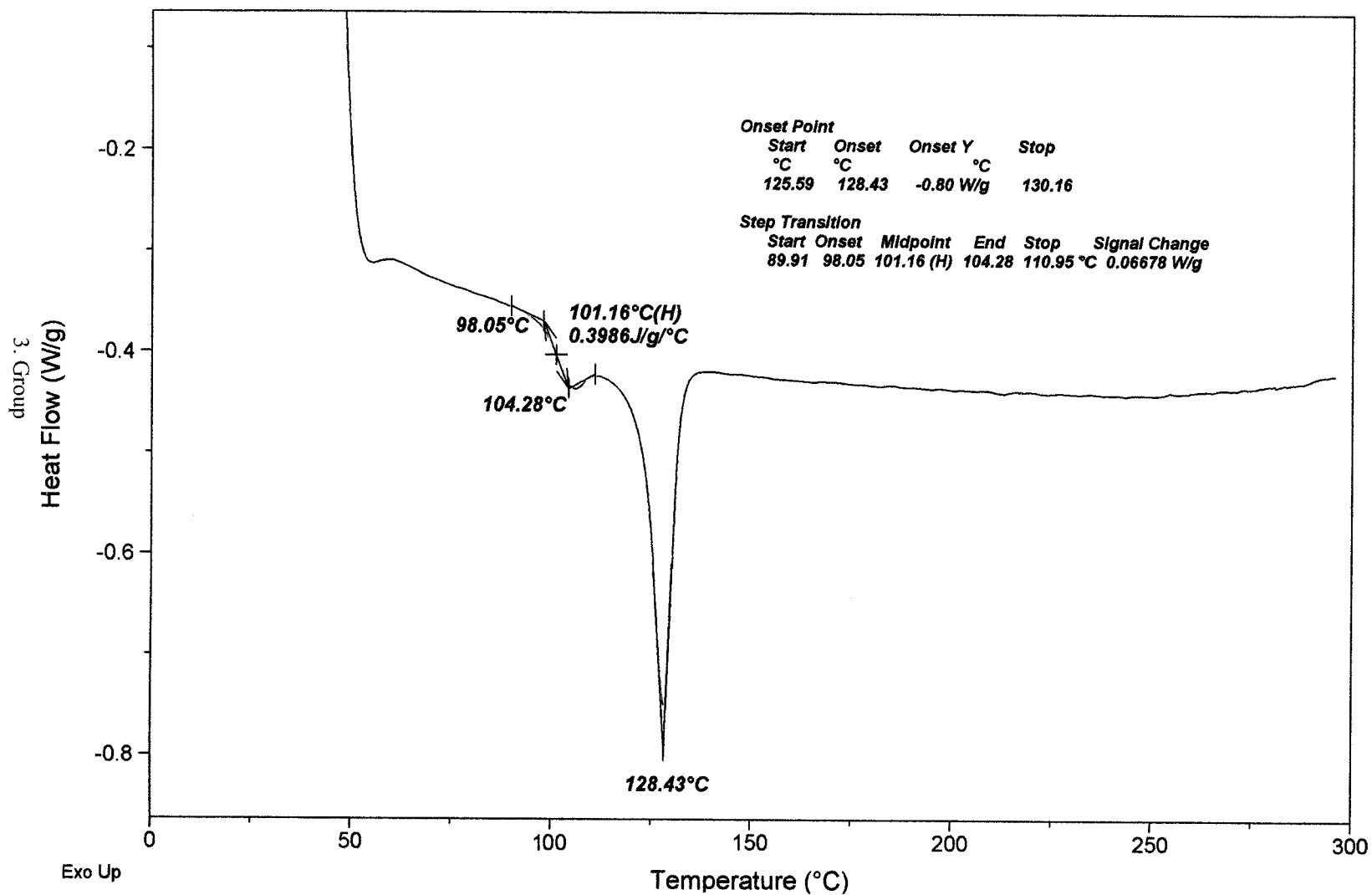


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Sample: numune 5
Size: 18.0000 mg

DSC

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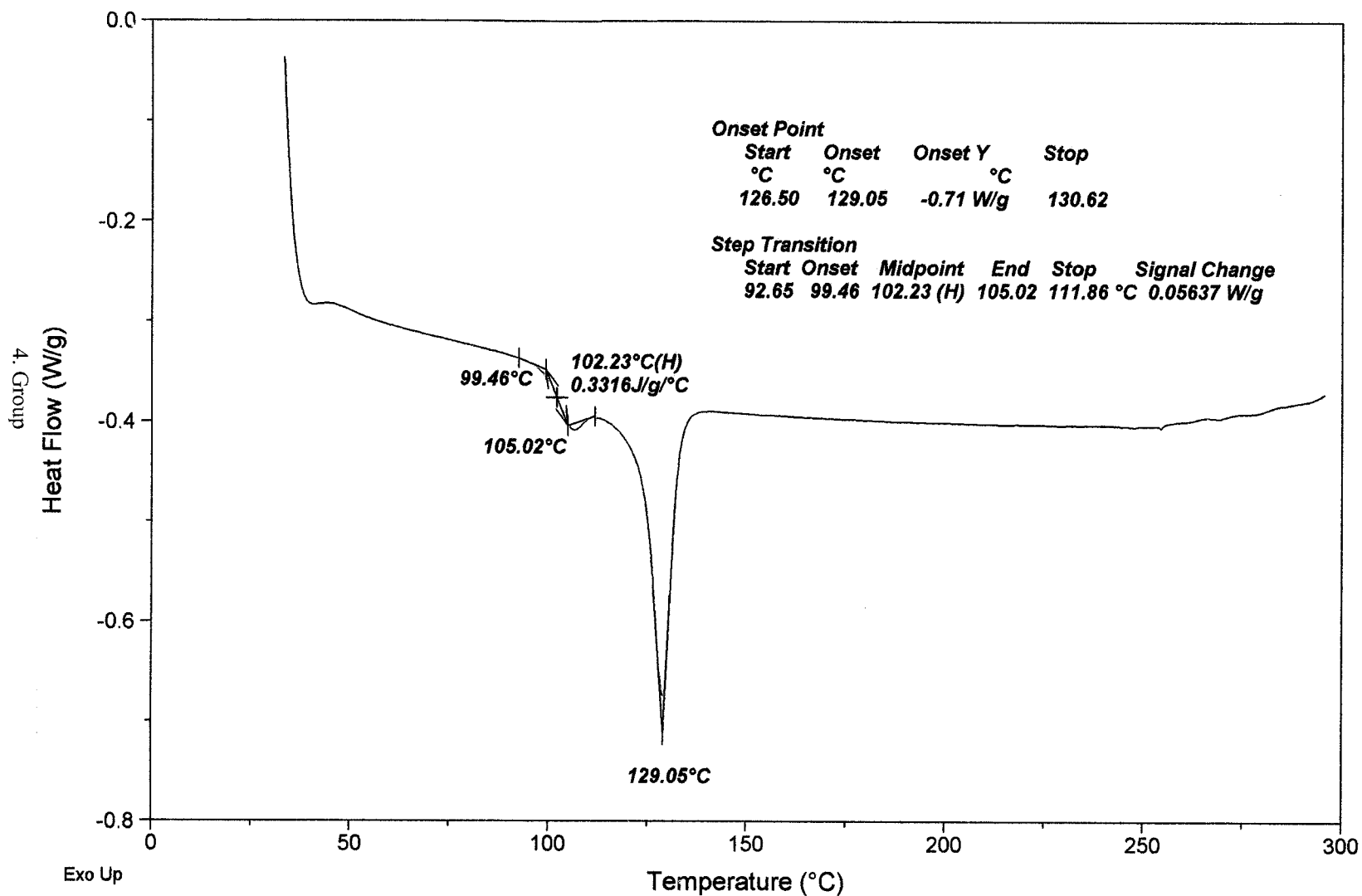


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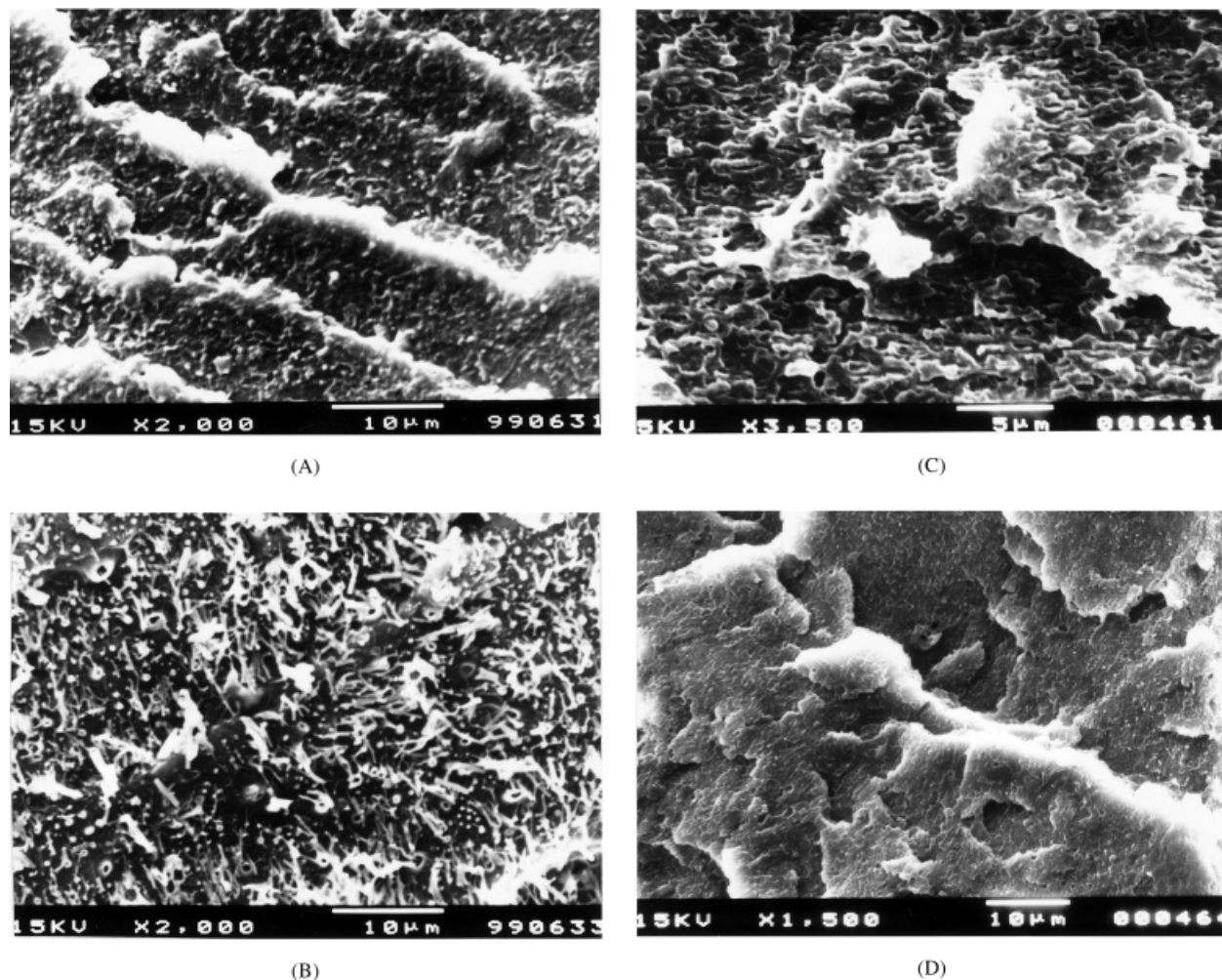


Figure 4 SEM micrographs revealing the appearance of the fracture surfaces of the PS/HDPE/SBS polymer alloys: (A) PS/HDPE, group 1 polymer blend (original magnification $\times 2000$), (B) PS/HDPE/SBS, group 2 polymer alloy (original magnification $\times 2000$), (C) PS/HDPE/SBS, group 3 polymer alloy (original magnification $\times 3500$), and (D) PS/HDPE/SBS, group 4 polymer alloy (original magnification $\times 1500$).

ratio resulted in the most compatible PS/HDPE/SBS polymer alloy.

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