

Properties of Acrylonitrile–Butadiene–Styrene/Polycarbonate Blends with Styrene–Butadiene–Styrene Block Copolymer

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ABSTRACT: The importance of alloys and blends has increased gradually in the polymer industry so that the plastics industry has moved toward complex systems. The main reasons for making polymer blends are the strengthening and the economic aspects of the resultant product. In this study, I attempted to improve compatibility in a polymer blend composed of two normally incompatible constituents, namely, acrylonitrile–butadiene–styrene (ABS) and polycarbonate (PC), through the addition of a compatibilizer. The compatibilizing agent, styrene–butadiene–styrene block copolymer (SBS), was added to the polymer blend in ratios of 1, 5, and 10% with a twin-screw extruder. The morphology

and the compatibility of the mixtures were examined by scanning electron microscopy and differential scanning calorimetry. Further, all three blends of ABS/PC/SBS were subjected to examination to obtain their yield and tensile strengths, elasticity modulus, percentage elongation, Izod impact strength, hardness, heat deflection temperature, Vicat softening point, and melt flow index. © 2004 Wiley Periodicals, Inc. *J Appl Polym Sci* 93: 2521–2527, 2004

Key words: alloys; blends; compatibilization; elastomers; polycarbonates

INTRODUCTION

Polymer blends are composed of two or more polymers or copolymers. If a blend is incompatible, a compatibilizer is added to the blend to bind the structure together. These kinds of structures are then called *polymer alloys*. The acrylonitrile–butadiene–styrene (ABS)/polycarbonate (PC) structure is normally an incompatible blend, but with the addition of styrene–butadiene–styrene (SBS) copolymer, this problem of incompatibility is overcome.^{1,2}

The most important factor for improving the performance of polymer blends and alloys is choosing the right materials. Moreover, the right mixing conditions, the right compatibilizer, and control of blend of the resultant product are also very important.³

In the past, ABS and PC alloys have been produced with various compatibilizers. Jin et al. used poly(methyl methacrylate) as a compatibilizer for ABS/PC polymers.⁴ Zhang et al. used ABS-*g*-maleic anhydride for the ABS/PC blend.⁵ Hamada and Tsunasawa investigated the relation between flow marks and the internal structure of thin PC/ABS blends.⁶

Pastorini and Nunes researched the mechanical and thermal behaviors of the ABS/PC blend with the addition of mica.⁷ Chaudhry et al. investigated the effects of the process conditions on the morphological structures

of the PC/ABS polymer.⁸ Another interesting study was done by Tjong and Jiang; they studied the effects of potassium titanate whiskers on the mechanical and thermal properties of the ABS/PC polymer blend.⁹

Several articles have reported the use of SBS block copolymer in the toughening of some polymers. Taşdemir and Yıldırım (with polystyrene/high-density polyethylene),¹⁰ Radonjic et al. (with polypropylene/polystyrene),¹¹ Picchioni et al. (with syndiotactic polystyrene),¹² and Mantovani et al. [with poly(butylene terephthalate)]¹³ used SBS as a modifier in their blends. These researchers showed that the performance properties, that is, the mechanical, thermal and compatibility, of the ABS/PC polymer can be changed with different compatibilizers.

In this study, incompatible ABS and PC polymers were made compatible with the addition of SBS. SBS was added at different ratios to the ABS/PC polymer blend, and changes in the mechanical and thermal properties and microstructure were observed.

EXPERIMENTAL

Four different polymer alloys were prepared, each with different ratios of ABS, PC, and SBS, in a ABS/PC/SBS system, as shown in Table I.

Table II shows the physical and mechanical properties of the plastic materials used in the blends.

Samples with various proportions of polymer blends were produced between 85 and 230°C at a

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TABLE I
Composition of ABS/PC/SBS Polymer Alloys

Group	ABS (%)	PC (%)	SBS (%)
1	70	30	0
2	69.3	29.7	1
3	66.5	28.5	5
4	63	27	10

pressure of 20 bar and a production rate of 306 rpm with a twin-screw extruder (Maris-TM40MW, Maris America Corp., Baltimore, MD). Table III outlines the extrusion and injection conditions.

Tensile test samples were prepared according to ISO 294 with an Arburg injection-molding machine (Arburg GmbH Co., Lossburg, Germany), as shown in Table III. Tensile and impact tests were conducted, respectively, according to ISO 572.2 at a crosshead speed of 5 mm/min and ISO 180 with a Zwick machine (Zwick GmbH, Ulm, Germany). Melt flow index (MFI) values were obtained according to ASTM D 1238 with Zwick test equipment. Differential scanning calorimetry (DSC) studies were undertaken with a SETARAM DSC 131 (Scientex Pty., Ltd., Victoria, Australia). The heat deflection temperature (HDT) and Vicat softening point of the samples were determined with a Ceast 6505 machine (Ceast SPA, Pianezza, Italy). To investigate their microstructure, the samples were coated with carbon to a thickness of 40 Å on a Polaron SC 502 (Gala Instrument GmbH, Bad Schwalbach, Germany) and studied with a JSM-5410 LV Jeol scanning electron microscope (Jeol, Peabody, MA) operated at 15 kV.

RESULTS AND DISCUSSION

With the increased amount of SBS in ABS/PC/SBS, the yield and tensile strengths, hardness, and elasticity modulus of the resultant material decreased, whereas the percentage elongation and Izod impact strength increased. The mechanical properties of the ABS/PC/SBS polymer alloys are given in Table IV and Figure 1.

TABLE III
Extrusion and Injection Conditions for Preparing the Polymer Blends

Property	Extrusion	Injection
Temperature (°C)	180–230	210–230
Screw speed (rpm)	306	—
Pressure (bar)	20	40
Dwell time in mold (s)	—	10
Cooling water (°C)	85	40

The thermal properties of the polymer alloys are given in Table V. As shown in Table V, the MFI value of the 70/30 ABS/PC polymer blend was 5.90 g/10 min (200°C, 5 kg). However, the addition of SBS to the ABS/PC polymer blend resulted in lower MFI values. However, with the increasing SBS concentration, the MFI value of the alloy increased.

On heating, the glass-transition temperature (T_g) of ABS in the ABS/PC/SBS polymer alloys was observed at 105.98°C (heating rate = 10°C/min); on further heating, T_g of PC was found to be 132.64°C. The addition of SBS did not appear to alter the heating curves to any significant degree. The temperature data obtained from DSC measurements are also shown in Table V, and the DSC curves are presented in Figure 2. The HDT and Vicat softening point measurements showed that the addition of SBS to the ABS/PC blend reduced the HDT and Vicat softening point values, as shown in Table V. The HDT experiment was started at room temperature with a heating rate of 120°C/h and under a load of 1.8 MPa.

The fracture surfaces (charpy specimen) of the polymer alloys examined by scanning electron microscopy (SEM) revealed that in the absence of SBS, the phases present in the blend did not appear to adhere well (group 1). However, the addition of 10% SBS considerably enhanced the adhesion and distribution of these phases (group 4), as shown in Figure 3.

CONCLUSIONS

With increasing amounts of SBS in ABS/PC/SBS, the yield and tensile strengths, hardness, and elasticity

TABLE II
Physical and Mechanical Properties of the Polymers

Property	ABS resin ¹⁴	PC resin ¹⁵	SBS resin ¹⁶
Commercial name	ABS	Lexan	Kraton
Type	750 SW	144 R	D-4271 CS
Density (g/cm ³)	—	1.200	0.9400
Styrene rate (%)	—	—	45
MFI (g/10 min)	35 (220°C, 10 kg)	12 (300°C, 1.2 kg)	10 (200°C, 5 kg)
Hardness (Shore A)	—	—	72
Tensile strength (MPa)	49	63	26
Water absorption (% in 24 h)	0.3	0.1	—
Elongation at break (%)	45	—	1000
Flexural strength (MPa)	65	90	—

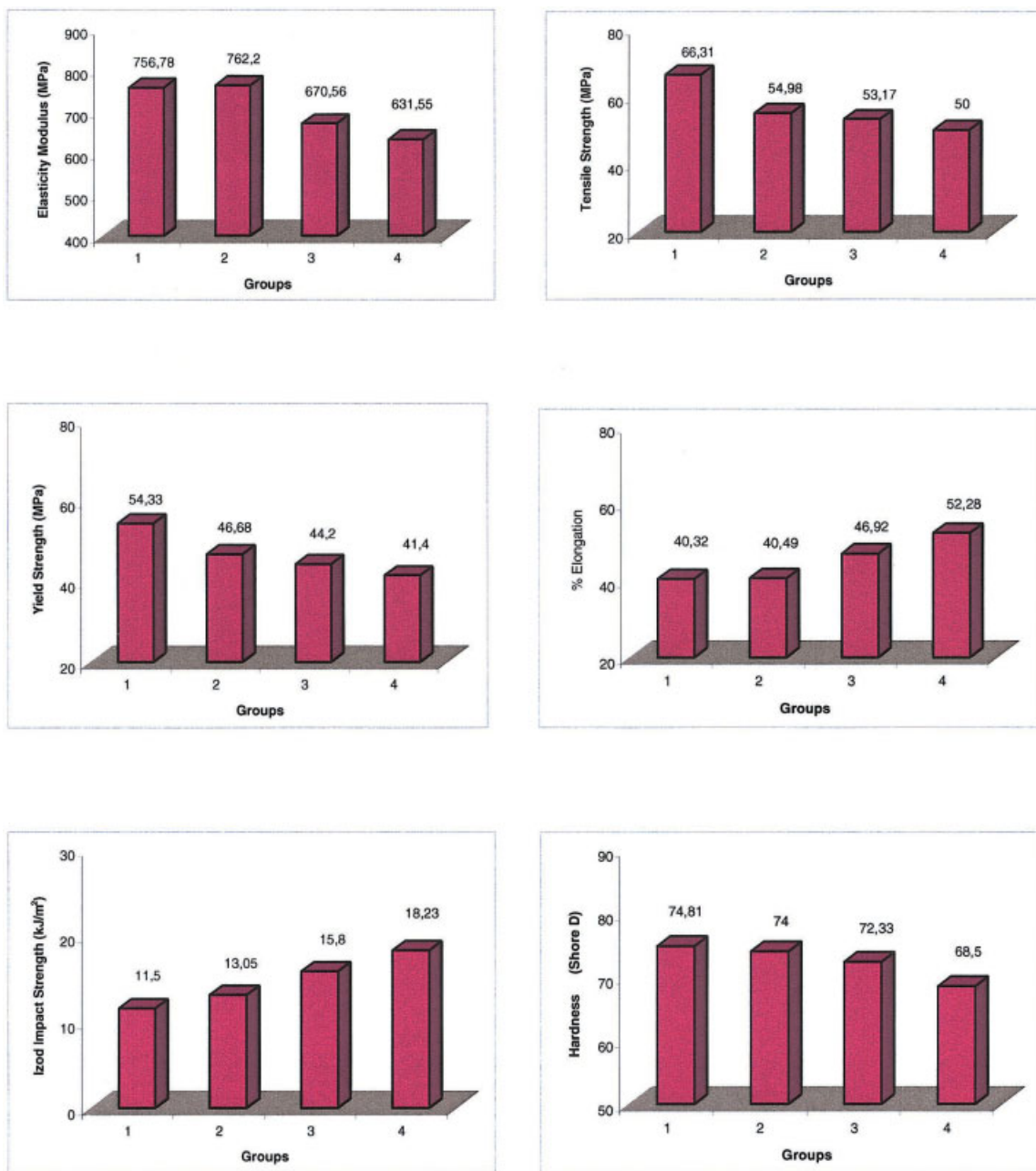


Figure 1 Changes in the mechanical properties of the ABS/PC/SBS alloys with the addition of SBS.

TABLE IV
Changes in the Mechanical Properties of the ABS/PC/SBS Alloys with the Addition of SBS

Mechanical property	Group 1	Group 2	Group 3	Group 4
Elasticity modulus (MPa)	756.78	762.20	670.56	631.55
Yield strength (MPa)	54.33	46.68	44.20	41.40
Tensile strength (MPa)	66.31	54.98	53.17	50.00
Elongation (%)	40.32	40.49	46.92	52.28
Hardness (Shore D)	74.81	74.00	72.33	68.50
Izod impact strength (kJ/m ² , notched)	11.50	13.05	15.80	18.23

TABLE V
Thermal the Properties of ABS/PP/SBS Polymer Alloys

Property	Group 1	Group 2	Group 3	Group 4
MFI (g/10min, 200°C, 5 kg)	5.90	3.98	4.86	5.36
HDT (°C, 1.80 MPa)	92.90	91.80	91.20	88.50
Vicat softening point (°C, 1 kg)	115.65	115.60	113.00	110.50
DSC (°C)				
ABS (T_g)	105.98	104.57	104.23	104.96
PC (T_g)	132.64	≈131.0	≈131.0	≈131.0

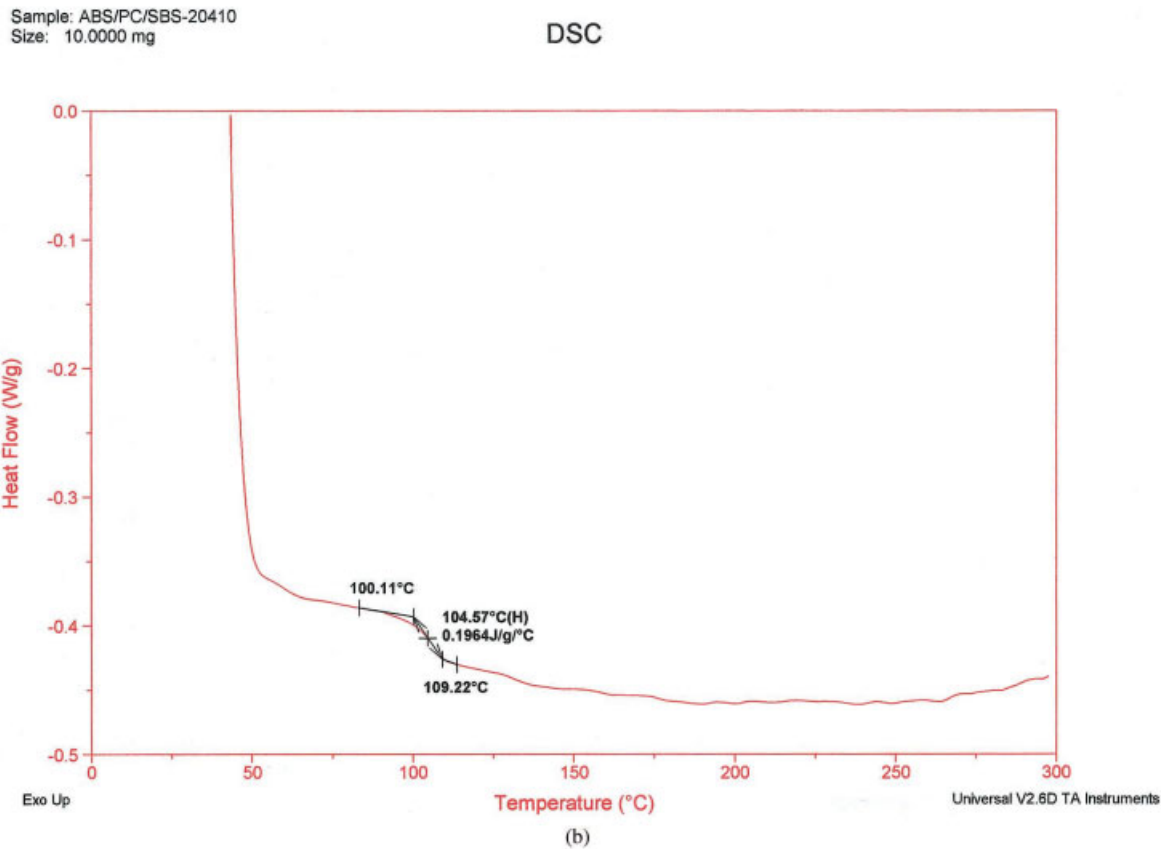
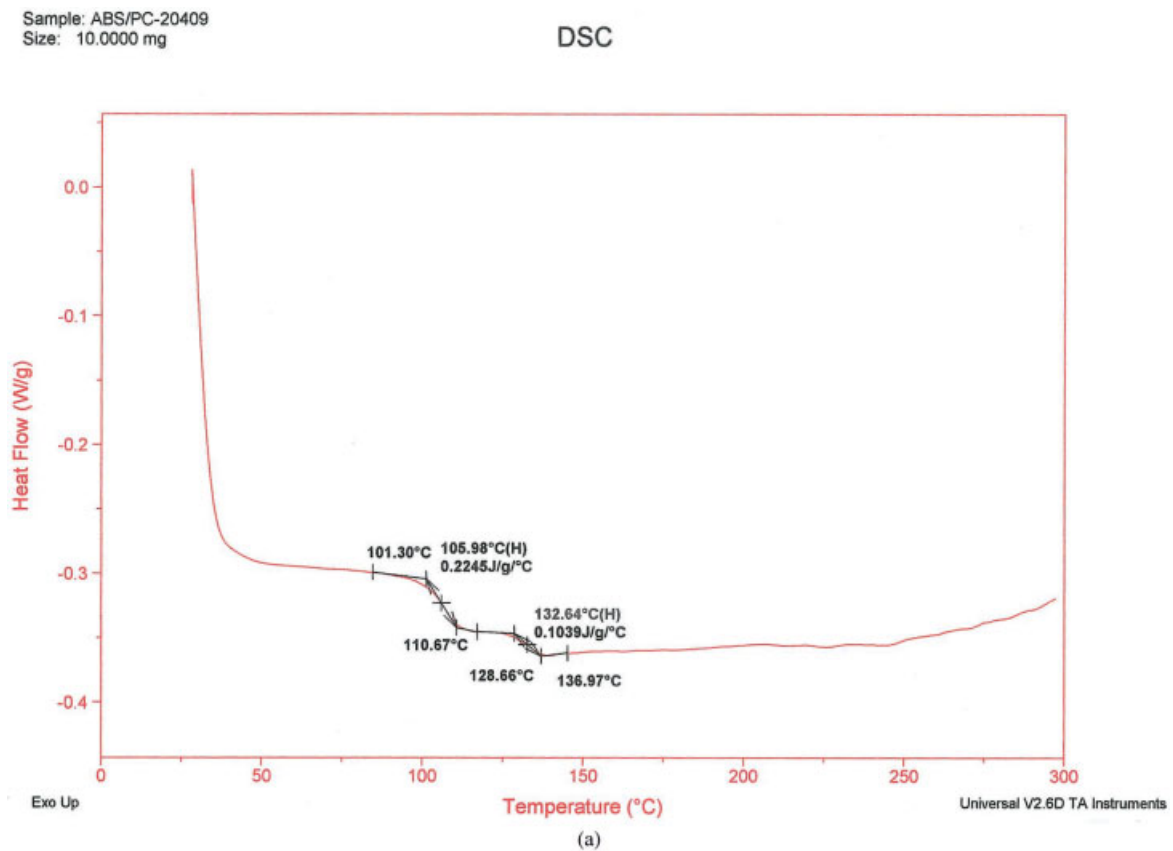
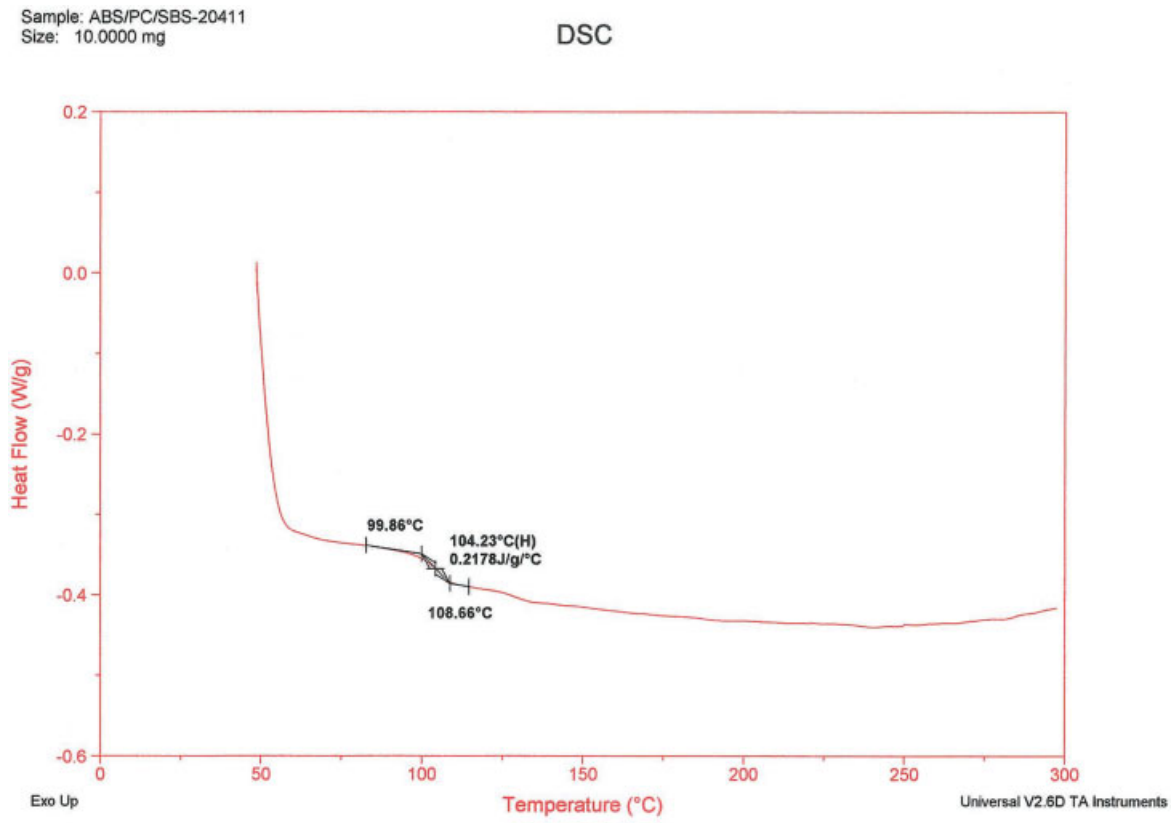
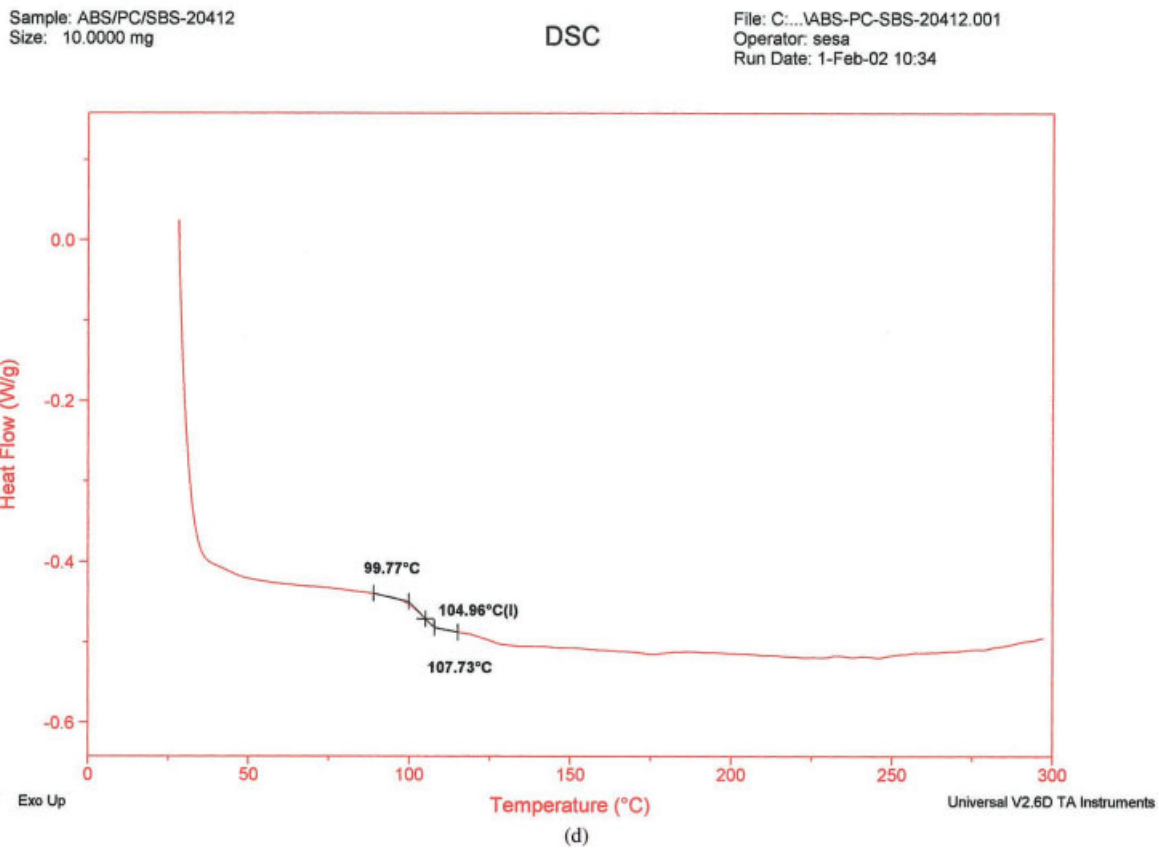


Figure 2 DSC curves for the ABS/PC/SBS polymer alloys: (a) group 1, (b) group 2, (c) group 3, and (d) group 4.



(c)



(d)

Figure 2 (Continued from the previous page)

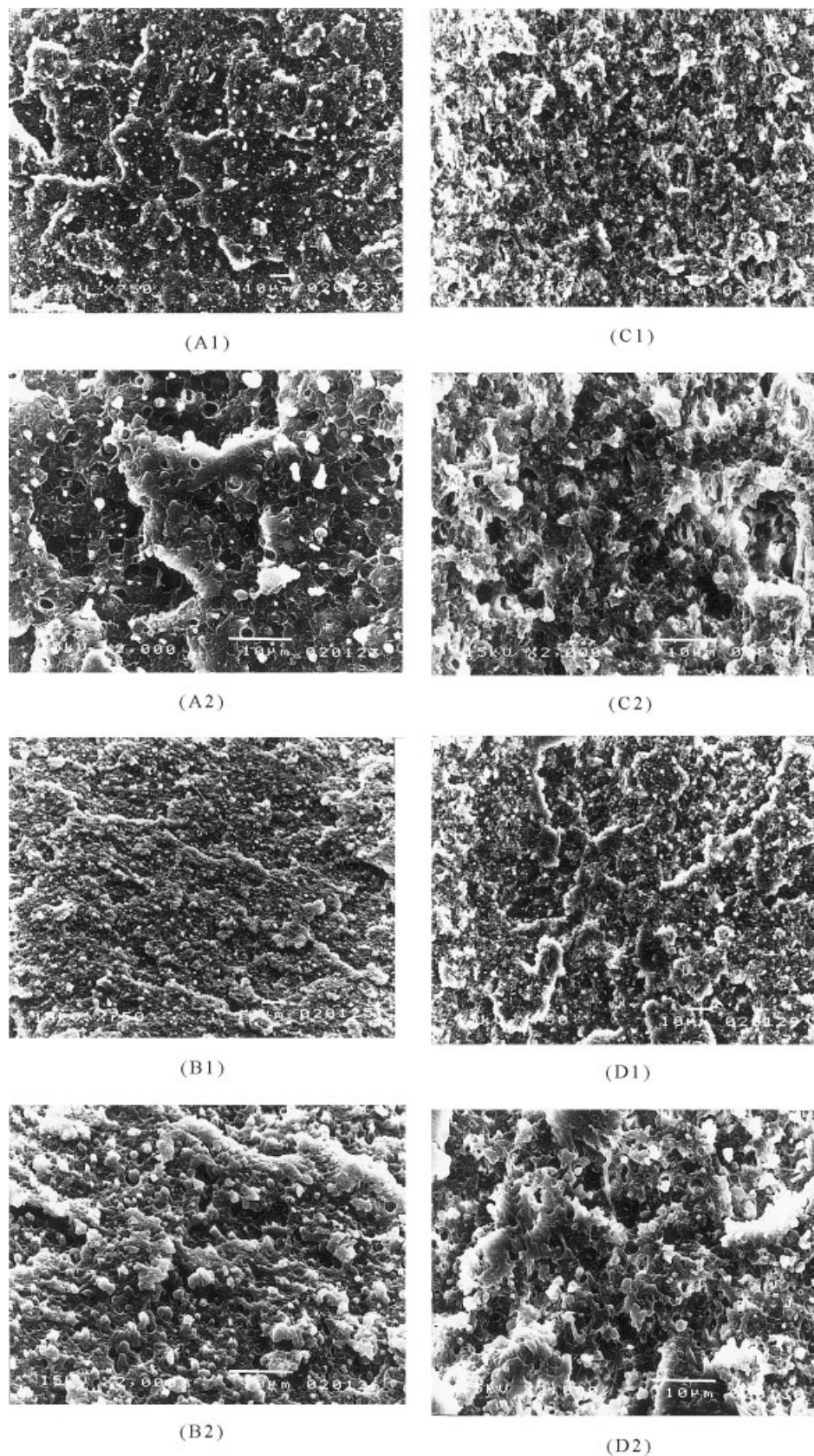


Figure 3 SEM micrographs revealing the appearance of the fracture surfaces of the ABS/PC/SBS polymer alloys (at magnifications of 750 and 2000 \times): (A) group 1, (B) group 2, (C) group 3, and (D) group 4.

modulus of the resultant materials decreased, whereas the percentage elongation and Izod impact strength increased. SBS showed more elastomeric character than the other two materials. Therefore, with the introduction of SBS to the system, the polymer blend was softened, and the Izod impact strength and percentage elongation of the materials increased, whereas the hardness, yield strength, tensile strength, and Young's modulus of the materials decreased. The MFI value of the 70/30 ABS/PC polymer blend was 5.90 g/10 min (200°C, 5 kg). However, the addition of SBS to the ABS/PC polymer blend resulted in lower MFI values. When the SBS concentration was increased, the MFI value of the alloy increased. This was because SBS showed more elastomeric character. On heating, T_g of ABS in the ABS/PC/SBS polymer alloys was observed at 105.98°C. On further heating, T_g of PC was 132.64°C (heating rate = 10°C/min). The addition of SBS did not appear to alter the heating curves to any significant degree because SBS showed more elastomeric character than the other two materials.

Measurements of HDT (with the experiment started at room temperature with at a heating rate of 120°C/h and under a load of 1.8 MPa) and the Vicat softening point showed that the addition of SBS to the ABS/PC blend decreased these values. The fracture surfaces (charpy specimen) of the polymer alloys examined by SEM revealed that in the absence of SBS, the phases present in the blend did not appear to adhere well [Fig. 3(A1,A2)]. However, the addition of SBS considerably enhanced the adhesion and distribution of these phases [Fig. 3(B1–D2)]. It was also apparent that 10% SBS markedly improved the adhesion, as evi-

denced by a more coherent morphology. Therefore, the addition of SBS to the ABS/PC blend resulted in a decrease in the elasticity modulus, the tensile and yield strengths, and hardness values, whereas the percentage elongation and Izod impact strength increased.

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