

# Mechanical, Thermal and Morphological Properties of Environmentally Degradable ABS and Poly(vinyl alcohol) Blends

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**ABSTRACT:** Blends of acrylonitrile–butadiene–styrene (ABS) with 5, 10, 15, and 20 wt % of poly(vinyl alcohol) (PV) were prepared by extruding in a corotating twin screw extruder. The ABS material was blended with PVA with the objective to enhance the degradability of ABS. The extrudate strands were cut into pellets and injection molded to make test specimens. These ABS/PVA blend specimens were tested for physicommechanical properties like tensile strength, elongation, modulus of elasticity, abrasion resistance, density, and water absorption. These blends were further characterized by melt flow Index, dif-

ferential scanning calorimetry, thermogravimetry analysis, and scanning electron microscopy. The morphological analysis reveals the existence of PVA domains in the ABS matrix. Differential scanning calorimetry thermograms indicates the chemical interaction between ABS and PVA domains. The prepared blends show enhanced environmental and thermal degradation. © 2007 Wiley Periodicals, Inc. *J Appl Polym Sci* 106: 1048–1052, 2007

**Key words:** acrylonitrile–butadiene–styrene; poly(vinyl alcohol); degradable; mechanical; thermal properties

## INTRODUCTION

Traditional applications of plastic materials are mostly based on their relative inertness to environmental degradation, but, now the use of plastic materials has accelerated to the extent that the disposal has become increasingly difficult. So, there is a growing demand for environmentally degradable plastics. As a viable alternative, it is intended to make degradable blends of synthetic plastics with degradable polymers to generate versatile polymeric products which find applications in almost all walks of life. Among the synthetic thermoplastics materials, acrylonitrile–butadiene–styrene (ABS) is a popular plastics in industrial as well as commodity applications and being used in many fields like defence, aerospace, automobile, electrical, computer, telecommunications, and appliance applications. ABS is a hard and tough thermoplastic terpolymer with good impact strength and surface gloss. However, it is resistant to environmental degradation after its use and becomes a critical problem to the plastics industries, which makes it necessary to modify ABS with biodegradable polymers. Generally synthetic thermoplastics are modified

with starch<sup>1–7</sup> or natural fibers<sup>8–12</sup> to make it environment friendly. But not much focus on the use of poly(vinyl alcohol) (PVA) as biodegradable polymer in modification of synthetic plastics. PVA is a synthetic polyhydroxy polymer, having very good water absorption and biocompatibility. PVA is one of a few completely biodegradable synthetic polymer<sup>13</sup> available today, which is usually synthesized by hydrolysis of polyvinyl acetate. However, PVA as such can not be used as a plastic, because of its higher water absorption and weak thermal stability. Hence it is intended to be used as a modifier in ABS through blending process, because blend preparation is the best and economically viable option to modify the plastics, this is manifested by growing number of monographs and publications<sup>14–19</sup> on blends.

With the ongoing interest in hydrophilic/biodegradable polymers,<sup>20–24</sup> in the present study ABS was blended with PVA in different proportions and its photodegradability was assessed in terms tensile strength. There are four synergistic mechanisms by which plastic materials degrade in the aquatic and terrestrial environments. They are microbial degradation, degradation by macro-organism, photo-degradation, and chemical degradation. The photo degradation is a highly studied degradation process, where absorption of UV light leads to decomposition of plastic molecules. Photodegradation may be enhanced by the incorporation of photo-active chemical groups—vinyl ketone and carbon monoxide into a polymer chain. Photo degradation has the potential of facilitat-

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**TABLE I**  
Composition of ABS and PVA Blends

Sample code	Composition in weight percentage	
	ABS	PVA
A	100.00	0.00
B	95.00	5.00
C	90.00	10.00
D	85.00	15.00
E	80.00	20.00

ing biodegradation by reducing the molecular weight and introducing oxygen groups on the chain, which also facilitates chemical degradation.

## EXPERIMENTAL

### Materials

The plastic raw materials used in this study were ABS (Absolac 300, with MFI of 4 gm/10 min, density of 1.06 g/cc) and PVA (Mn 1400, 90% hydrolyzed) supplied by Bayer ABS and Poly Chem, India, respectively.

### Compounding and specimen preparation

ABS and PVA raw materials were premixed in tumbling mixer for 15 min as per the composition given in Table I, after predrying in hot air oven at 75°C for 3 h, and then melt blended in 25 mm dia. twin screw corotating extruder (Berstorff, Germany) having L/D ratio 1 : 33 in the temperature range of 175–210°C at 180 rpm. The extrudate strands were cut into pellets and injection molded to make test specimens. The test specimens as per ASTM standard were made in M/S R.H. Winsor India SP-130 automatic injection molding machine in the temperature range of 180–225°C and injection pressure at 150 MPa.

### Mechanical properties

The tensile tests were carried out in Universal testing machine (Llyods, UK, Model LR 100 K) as per ASTM D 638 standard with cross-head speed of 50 mm/min.

Abrasion resistance was tested in the standard Abrasion tester (Taber Abraser Model 503, USA) as per ASTM D 1044.

### Characterization techniques

Differential scanning calorimetry and thermogravimetric analysis were carried out in Dupont 910, USA, thermal analyzer system at the rate of 10°C/min from ambient to 300°C and 20°C/min from ambient to 600°C, respectively. For morphological analysis, approximately 6 mm × 6 mm section was cut from the injection molded specimens and was mounted on a specimen holder. A gold coating of ~ 200 Å thick was deposited on the surface of the specimen, kept within the vacuum evaporator and then the micrographs of these material surface was taken up in Jeol JSM 5300 SEM, Japan. Melt flow analysis was carried in melt flow index tester (Devanport, UK, Type 7273) at 190°C and 2.16 kg load as per ASTM D 1238. Density was measured for extrudate material as per ATSM D 792. Water absorption was measured for injection molded discs of 50 mm dia. as per ASTM D 570.

### Weathering properties

The tensile specimens were subjected to accelerated weathering conditions for a period of 600 h in weather-o-meter (Heraeus Xenotest ALPHA, Germany) as per ISO 4892 (weathering for exterior parts) and tested for tensile strength before and after weathering and compared.

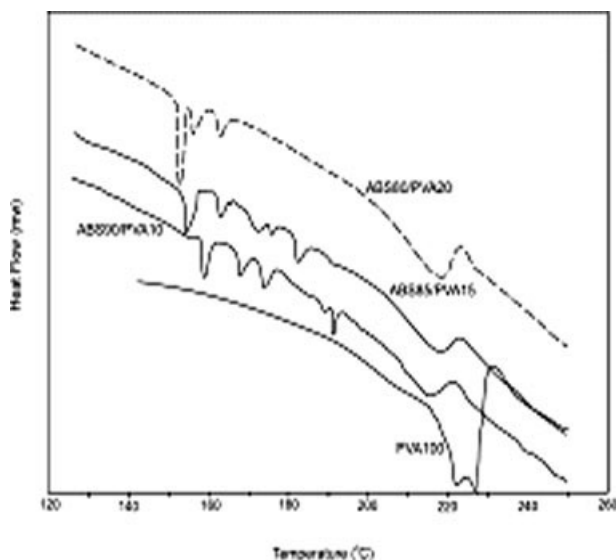
## RESULTS AND DISCUSSION

### Mechanical properties

The tensile and abrasion results of ABS and PVA blends at different PVA contents are given in Table II. From the Table II, it is interesting to note that the difference between tensile strength at yield (58.80 MPa) and tensile strength at break (48.76 MPa) of virgin ABS is reduced and merged (56.91 MPa) with increase in PVA content from 5 to 20 wt %. Further the percentage of elongation at break (20.53%) of vir-

**TABLE II**  
Effect of PVA Addition on Mechanical Properties of ABS

Sample code	Tensile strength at yield (MPa)	Tensile strength at break (MPa)	Percentage of elongation at break	Modulus of elasticity (MPa)	Abrasion for 1000 cycles (mg)
A	58.80	48.76	20.53	344.5	567
B	61.44	48.65	25.11	301.1	551
C	52.85	44.05	15.81	334.2	657
D	57.52	54.15	11.80	399.3	553
E	56.91	56.91	9.788	388.6	499

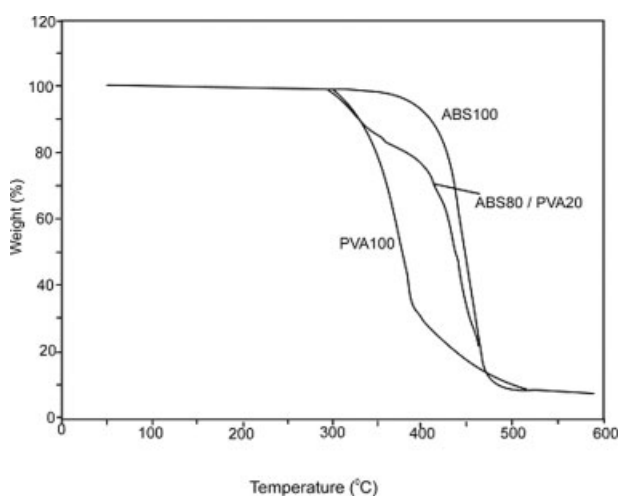


**Figure 1** DSC thermograms of ABS/PVA blends.

gin ABS reduced to 9.78%, modulus of elasticity increased from 344.5 to 388.6 MPa and the abrasion loss of virgin ABS (567 mg) reduced (499 mg) with increase in PVA content from 5 to 20 wt %. This may be due to the enhanced interaction between ABS and PVA with increase in PVA content, which reduces slippage of molecules during stretching and abrasion due to hydrogen bonding through hydroxyl groups.

#### Differential scanning calorimetry and thermogravimetry analysis

Differential scanning calorimetry (DSC) is a unique technique to analyze the interaction behavior of blends. From Figure 1, it is clear that ABS/PVA blends show multiple endothermic peaks because of the heterogeneous nature of ABS material. However, the increase in the percentage of PVA indicates reduc-



**Figure 2** TGA thermograms of ABS/PVA blends.

**TABLE III**  
Effect of PVA Addition on Thermal Stability of ABS

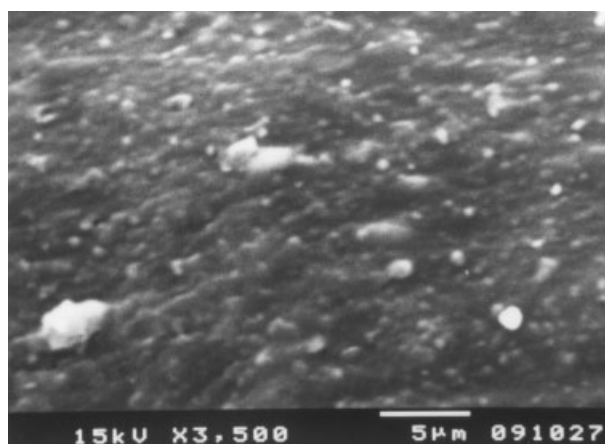
Composition(%)		Percentage of weight loss measured at (°C)				
ABS	PVA	300	350	400	450	500
100	0.00	Nil	Nil	6.6	60.0	91.2
80	20	Nil	18.0	23.2	68.0	91.2
0.00	100	Nil	24.0	68.8	83.2	91.2

tion in number and increase in size of endothermic peaks, which indicates the strong of interaction between ABS and PVA materials.

The thermogravimetry analysis (TGA) technique essentially involves continuous monitoring of weight of a sample as a function of temperature using sensitive micro-balance. Typical TGA thermogram obtained for ABS, PVA and its blend (ABS 80/PVA20) are shown in Figure 2 and the results are given in Table III. From the Figure 2 and Table III, it is clear that initial decomposition temperature of ABS is reduced with the addition of PVA. Virgin ABS shows only a weightloss of 6.6% at 400°C, whereas the ABS80/PVA20 blend shows a weightloss of 23.2% at the same temperature indicating reduced thermal stability with the addition of PVA. This may be due to the poor thermal stability of PVA, which shows a weightloss of 68.8% at the same temperature.

#### Morphological studies

The Scanning Electron Microscope photographs of neat ABS, the blends C, D, and E are shown in Figures 3–6, where Figure 3 corresponds to sample A, which has a relatively uniform surface morphology. Figure 4 corresponds to sample C which shows a discontinuous pattern of the surface because of the presence of second component (PVA). The surface morphology becomes irregular and discontinuous with increase of PVA content as can be seen from Figures 5 and 6



**Figure 3** Sample A.

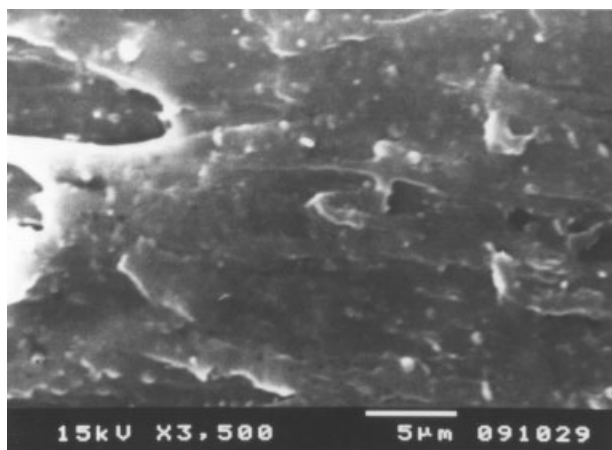


Figure 4 Sample C.

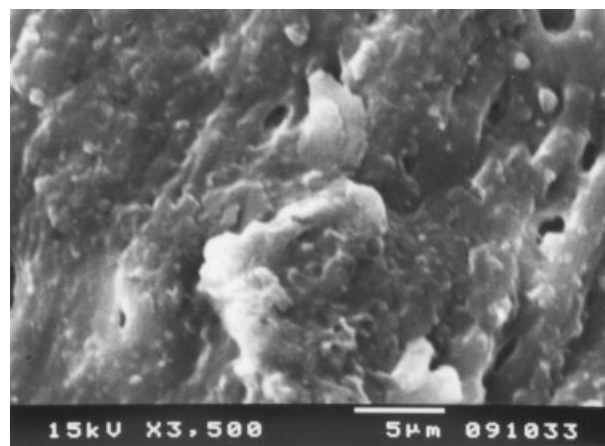


Figure 6 Sample E.

which shows more phase separation. The PVA phase domains are distributed in the ABS phase and the distribution size of PVA component becomes larger with increase of PVA content in blends. It may be noted that the irregularity introduced in the morphology may support dis-integration/degradation of the ABS material because the irregularity may provide an active site for micro-organisms.

#### Material flow index, density, and water absorption

The flow behavior of the ABS blends were determined by melt flow index (MFI) and reported in Table IV. Table IV shows reduction in MFI values from 3.934 to 2.490 g/10 min and increase of density from 1.059 to 1.100 g/cc, which further supports the interaction between ABS and PVA matrices.

Since PVA is a highly water absorbing material,<sup>23</sup> it is expected to have a higher water absorption as its proportion increases in the blends. But it is observed

from Table V, that there is only a marginal increase in water absorption. This may be due to the fact that the PVA is encapsulated by ABS matrix and hence, PVA material is not properly exposed to the surface to have higher water absorption.

#### Accelerated weathering

Environmentally degradable plastics are those which undergo degradation in environmental conditions. There are several environmental factors which seriously affect the plastics, of these factors, solar radiation is one of the most destructive of all factors. To evaluate the effect of environmental degradability on plastics due to solar radiation, Xenon arc type of light source is being used. Xenon arc type light source is the source which closely simulate the solar radiation conditions. To evaluate the degradability, the tensile specimens of ABS and its blends were subjected to accelerated ageing and then tensile strength was determined and compared with the values of unexposed samples and reported in Table VI. From Table VI, it is clear that there is a significant reduction in tensile strength with increase of PVA content in the blend after the accelerated ageing, which clearly indicates the enhanced degradability of the ABS/PVA blend compared to ABS material.

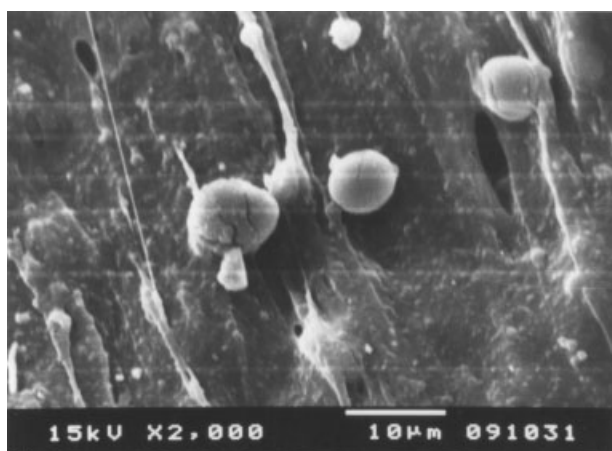


Figure 5 Sample D.

**TABLE IV**  
Effect of PVA Addition on Melt Flow Index (MFI) and Density of ABS

Sample code	Melt flow Index (g/10 min)	Density (g/cc)
A	3.934	1.059
B	3.864	1.069
C	3.852	1.080
D	2.976	1.086
E	2.490	1.100

**TABLE V**  
Effect of PVA Addition on Water Absorption of ABS

Sample code	Water absorption in percentage after						
	1 h	2 h	3 h	4 h	5 h	6 h	24 h
A	0.047	0.052	0.087	0.105	0.125	0.140	0.270
B	0.048	0.065	0.104	0.107	0.126	0.148	0.314
C	0.081	0.122	0.203	0.221	0.224	0.227	0.456
D	0.138	0.194	0.206	0.247	0.279	0.311	0.602
E	0.195	0.215	0.237	0.288	0.311	0.353	0.710

**TABLE VI**  
Effect of Accelerated Ageing on Tensile Strength of ABS/PVA Blends

Sample code	Tensile strength at break (MPa)		
	Before weathering	After weathering for 600 h	Percentage of reduction
A	48.76	37.72	22.62
B	48.65	36.04	25.92
C	44.05	29.07	33.99
D	54.15	29.45	45.59
E	56.91	28.17	50.50

## CONCLUSION

In this study, ABS is blended with PVA with the objective to enhance the degradability of ABS in the environmental conditions. The prepared blends were evaluated for degradability under accelerated ageing conditions and the results show enhanced degradability. The degradability in terms of tensile strength increases from 25 to 50% for the addition of PVA from 5 to 20 wt %. The morphological analysis shows the dispersion of PVA domains in the ABS matrix. DSC thermograms indicates chemical interaction between ABS and PVA domains. Further the addition of PVA shows enhanced water absorption which will support biodegradation.

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