

# Structure and Properties of Compatibilized Blends of Polyamide-6 and ABS

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## SYNOPSIS

Mechanical and Morphological properties of polyamide-6/ABS blend systems, compatibilized by styrene-maleic anhydride (SMA) copolymer, have been studied. The strength, modulus, and impact properties improved upon the addition of SMA. Morphological studies, using small angle light scattering, polarizing microscopy, and scanning electron microscopy, showed that SMA acts as a compatibilizer for the above system. © 1993 John Wiley & Sons, Inc.

## INTRODUCTION

Polymer blends and alloys are gaining importance in that they provide many useful properties, which are the result of a combination of properties of the individual components. Blends can have higher performance characteristics at reasonable prices and blends also provide the means for the reuse of plastic scrap. Polymer blends are generally considered to be mixtures of chemically different homopolymers or copolymers. These are mainly classified as (1) homogeneous blends, in which the components are miscible, and (2) heterogeneous blends, in which the components are immiscible. A mixture of two polymers that yield an immiscible blend can be made compatible by introducing a third component (compatibilizer), which is generally a block copolymer or a polymer with a solubility parameter value in between those of the two polymers to be blended. The compatibilization can take place by chemical or physical interactions. The present work involves blends of polyamide-6 (nylon-6) and acrylonitrile butadiene styrene terpolymer (ABS). Some work has been reported on such blend systems.<sup>1-7</sup> In the present study, an attempt has been made to study the morphology of nylon-6/ABS blends, compatibilized with a modified styrene maleic anhydride co-

polymer (SMA), and to correlate this morphology with the mechanical properties of the blends.

## EXPERIMENTAL

### Materials

Nylon-6 was supplied by Sri Ram Fibres Ltd., India, under the trade name Tufnyl SB 300 and ABS resin grade 300 was supplied by ABS Polymers, India. The modified styrene maleic anhydride resin (SMA) was supplied by Monsanto Chemical Company, USA. This is a terpolymer of styrene-maleic anhydride and methyl methacrylate in the ratio of 68/25/7 by weight.

### Sample Preparation

All blends were prepared by the melt mixing technique, using a single screw Betol BM 1820 extruder. Nylon-6 and ABS were dried in a vacuum oven at 70°C for over 24 h. The granules were dry mixed in appropriate ratios and were extruded at 260°C and at a low screw speed of 10 rpm to ensure a longer residence time, thus providing good mixing. The extruded strands were cooled by quenching in water and then were chopped into granules. Injection molding of the test specimens was done on a Windsor SP-I screw-type injection molding machine, using properly dried granules extruded earlier. Molding was performed at 260°C with an injection pressure of 150 Kg/cm<sup>2</sup>, keeping the mold at room temper-

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ature. Thin films were obtained from the blends and pure polymers by the compression molding technique on a Carver laboratory press at 220°C. These films were used for carrying out small angle light scattering (SALS) and polarizing microscopic (PM) studies.

### Mechanical Testing

Tensile and flexural testing was done on an Instron Universal Tester Model 430. Impact strength was measured on an FIE impact tester Model 0.42. All these tests were in accordance with ASTM test procedures. A minimum of five samples of each composition was tested.

### Morphology Studies

A photographic small angle light scattering (SALS) set-up was used for this study, fitted with an He—Ne gas laser of 5 mW output (wavelength = 6328 Å) as a light source. A polarizer was used to polarize the light in one selected direction. The surface of the polymer film was perpendicular to the beam of light. The polarizer was kept vertical with the analyzer horizontal and the pattern obtained was described as an  $H_v$  scattering pattern. A flat plate camera was used to record the light scattering pattern with an exposure time of 40 sec. A Leitz Laborlux 12 POL polarizing microscope was used for examining the microscopic structure of the blends. Impact fractured specimen surfaces were studied by scanning electron microscopy (SEM), using a

Cambridge S4-10 stereoscan microscope. A magnification of the order of 2000 was used for all the samples.

## RESULTS AND DISCUSSIONS

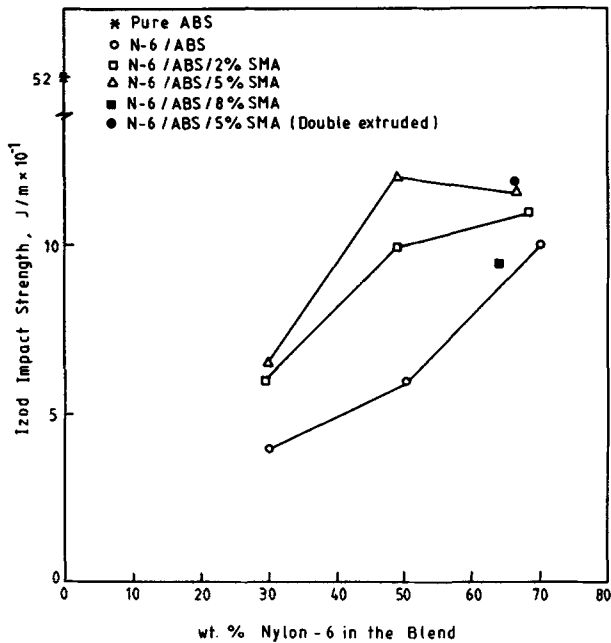
### Mechanical Properties

Notched and unnotched Izod impact strength values were determined for the blends and the results are presented in Table 1 along with other mechanical properties. Notched Izod impact values, plotted as a function of nylon-6 weight percentage, are shown in Figure 1. In the binary blends of Nylon-6/ABS, it was observed that the impact strength increased as the weight percentage level of nylon-6 was increased from 30 to 70. Upon the incorporation of 2% SMA in the binary blends, the impact strength increased for all the three ternary blends, as compared to the respective binary blends without any compatibilizer. The impact strength among these ternary compositions, containing 2% SMA, increased as the weight percentage of nylon-6 was increased from 29.4 to 68.6.

Addition of 5% SMA in the binary blends resulted in a further increase in the impact strength. There was an increase in the impact strength as the wt % of nylon-6 increased from 28.5 to 47.5%. However, further increase in the nylon-6 content did not show a significant increase. The double extruded ternary blends, containing 5% SMA and 66.5% nylon-6, showed higher impact strength than the sample of the same composition that was extruded only once.

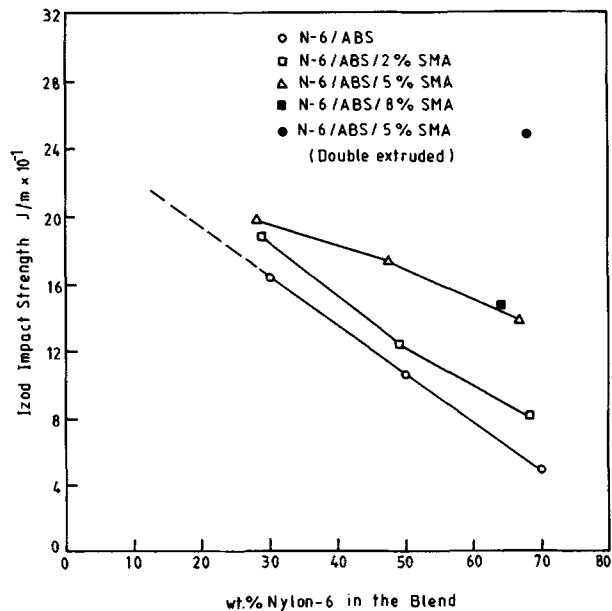
**Table I Mechanical Properties of Nylon-6/ABS/SMA Blends**

No.	Composition		Impact Strength		Flexural		Tensile	
			Unnotched	Notched	Strength	Modulus	Strength	Modulus
	Nylon-6/ABS	SMA(%)	J/M		(MPa)		(MPa)	
1	0/100	0	—	520	243	1002	26.9	550
2	70/30	0	49	100	29.8	638	31.5	425
3	50/50	0	107	60	23.8	690	26.5	520
4	30/70	0	164	40	25.0	993	24.5	425
5	70/30	2	81.9	110	31.0	751	36.4	520
6	50/50	2	123	100	28.6	920	32.7	513
7	30/70	2	189	60	27.9	500	31.4	533
8	70/30	5	139	115	32.0	856	36.6	398
9	50/50	5	172	120	29.8	792	34.5	460
10	30/70	5	197	50	28.4	900	33.3	428
11	70/30	8	147	5	32.9	829	38.7	466
12	70/30 (double extruded)	5	246	120	33.2	869	42.8	412

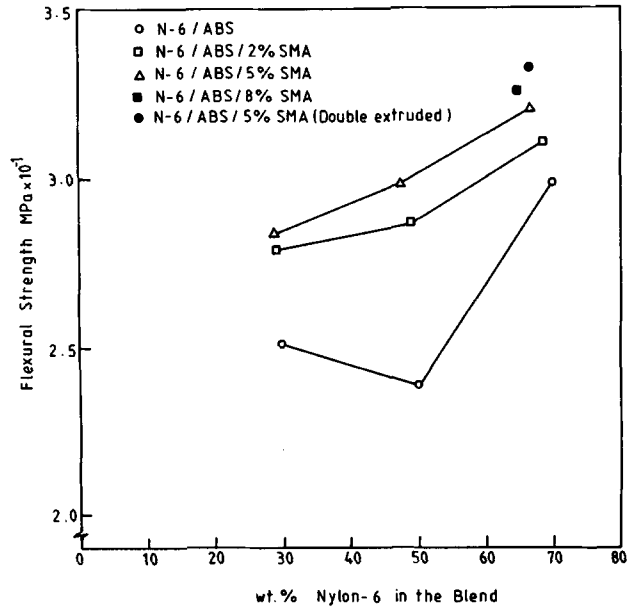


**Figure 1** Plot of notched Izod impact strength vs. nylon-6 content in the blend.

The ternary composition, containing 8% SMA and 64.4% nylon-6, had an impact strength, which was between the impact strength values of the binary blends (without compatibilizer) and ternary blends with 2% SMA. The incorporation of SMA increases the compatibility between the nylon-6 and ABS, which is reflected in the increased impact strength

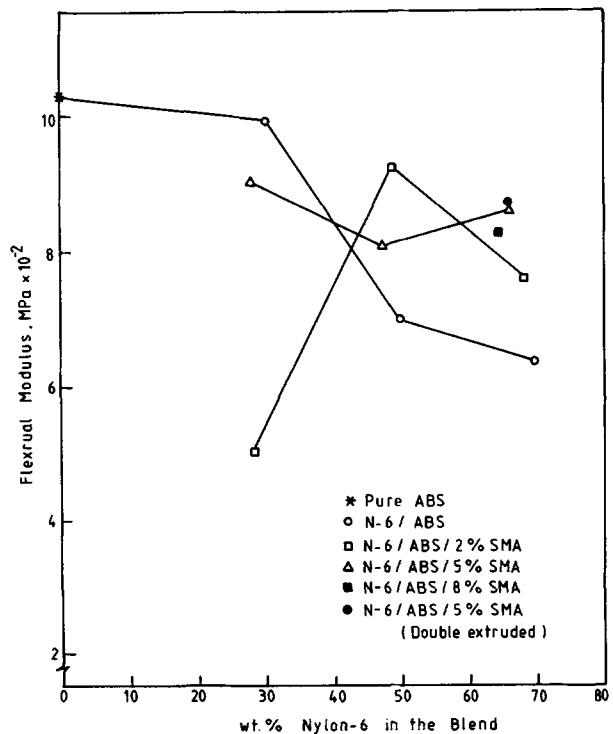


**Figure 2** Plot of unnotched Izod impact strength vs. nylon-6 content in the blend.



**Figure 3** Plot of flexural strength vs. nylon-6 content in the blend.

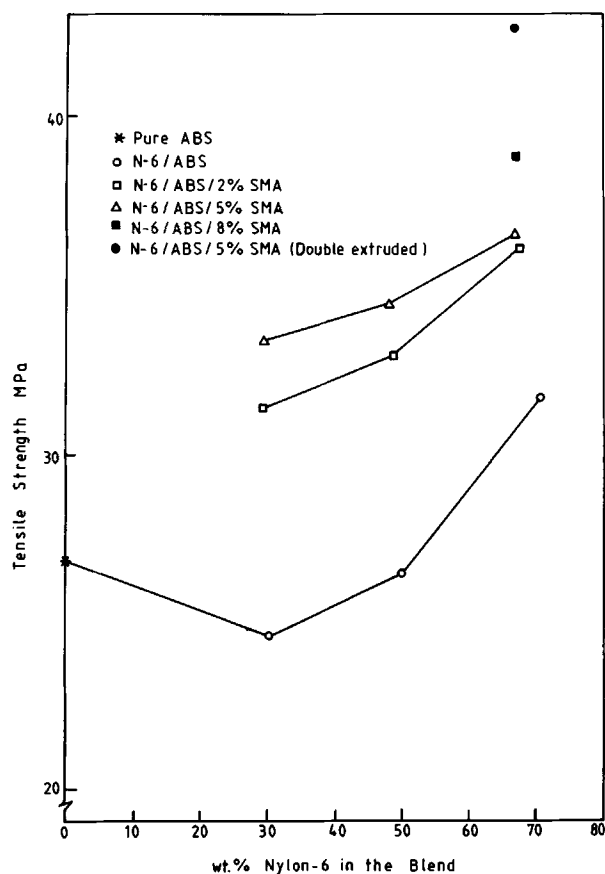
of these blends. Similar results have been reported by Otterson et al.<sup>7</sup> The improvement in impact properties, in the presence of SMA, can be attributed to the compatibilization of nylon-6 and ABS through the chemical reaction between the free terminal



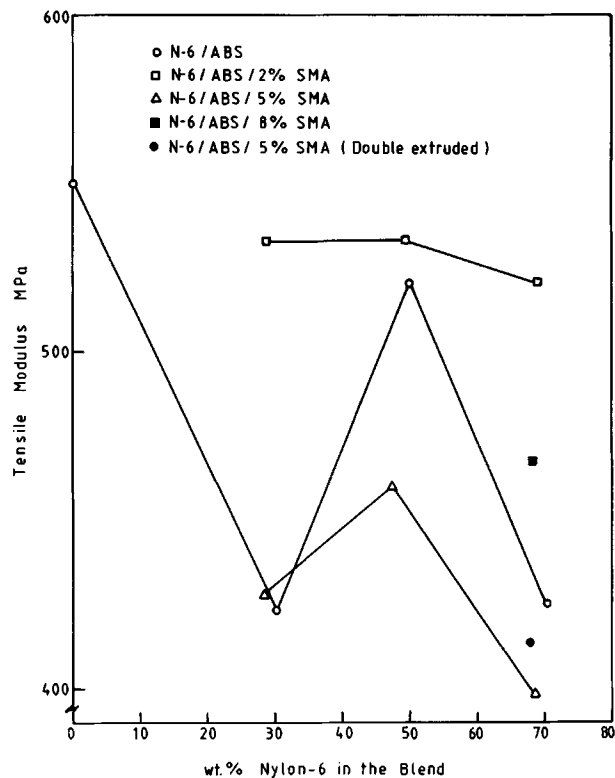
**Figure 4** Plot of flexural modulus vs. nylon-6 content in the blend.

amine groups of nylon-6 and the anhydride function in SMA. Such a reaction has been reported in the literature. Angola et al.<sup>2</sup> have shown that such a reaction occurs by performing IR studies; they have reported improved mechanical properties for the blend of a nylon-6/styrene acrylonitrile copolymer in the presence of SMA. A similar amidation reaction also has been reported in the case of nylon-6/poly(ethylacrylic acid) systems by Macknight et al.<sup>8</sup>

Unnotched Izod values are plotted as a function of the nylon-6 weight percentage in Figure 2. In the binary blends of nylon-6/ABS, the impact strength decreased as the weight percentage of nylon-6 increased from 30 to 70. Upon the incorporation of 2% and 5% SMA, there was an increase in the impact strength, as compared to those without the compatibilizer, but there was again a downward trend upon an increase in the nylon-6 content. The double extruded blend of nylon-6/ABS of 70/30, containing 5% SMA, showed superior properties with the highest impact strength of all the samples. In this case, better dispersion of phases would have



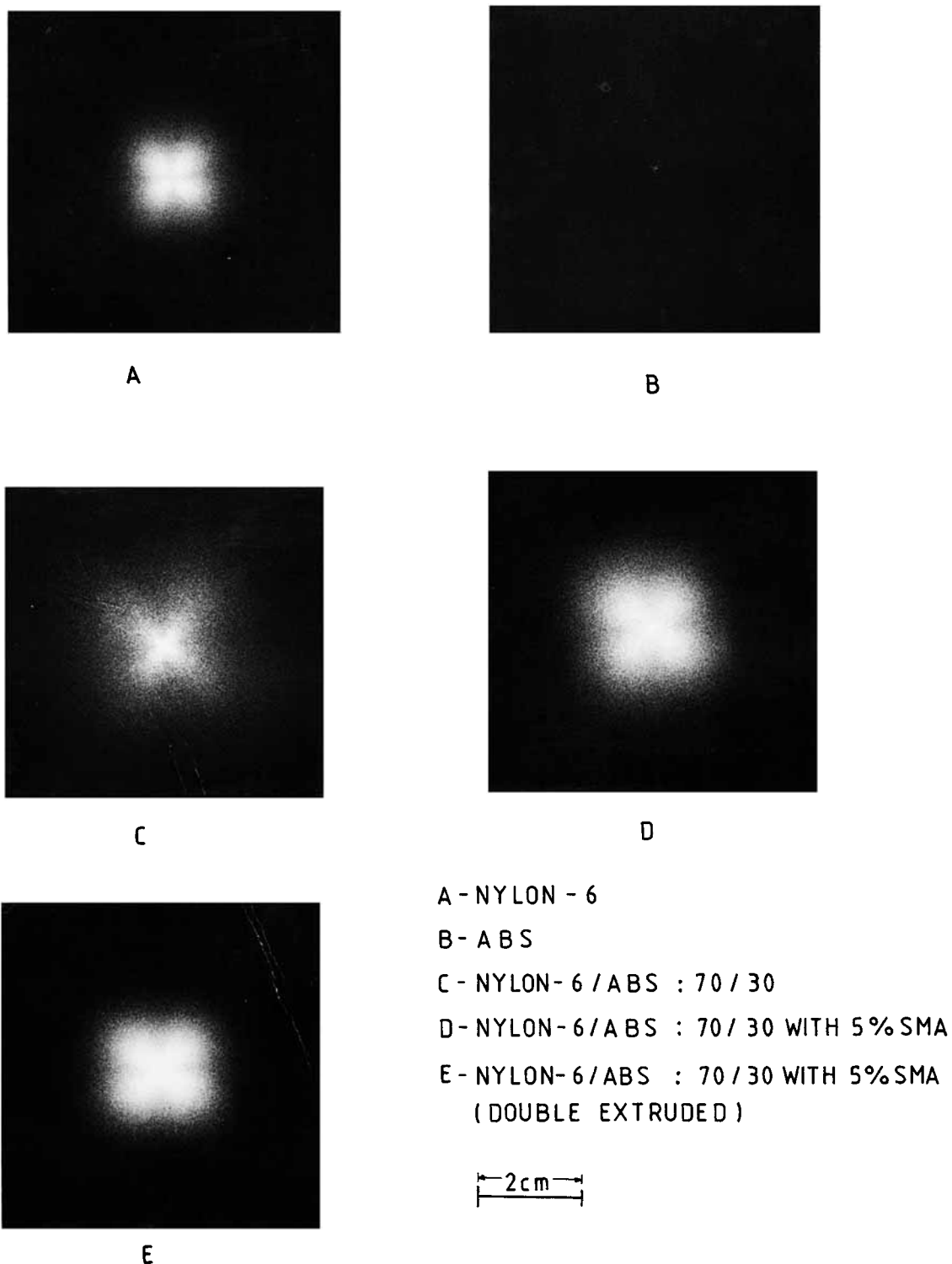
**Figure 5** Plot of tensile yield strength vs. nylon-6 content in the blend.



**Figure 6** Plot of tensile modulus vs. nylon-6 content in the blend.

been achieved, and also a greater extent of amidation reaction between SMA and nylon-6 would have occurred, resulting in improved strength values.

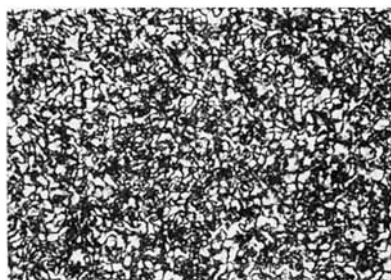
The flexural strength and modulus values are plotted as a function of nylon-6 content in Figures 3 and 4, respectively. For binary blends of nylon-6 and ABS, it was found that by increasing the percentage of nylon-6, the flexural strength increased, but the flexural modulus decreased. The incorporation of SMA in these blends showed better strength values. As the SMA content was increased from 2 to 5%, the corresponding strength properties also improved significantly. In this case also, the double extrusion seemed to enhance further the properties. Figures 5 and 6 show the plots of tensile yield strength and modulus values, respectively, as a function of nylon-6 content for the blends. The binary blends of nylon-6/ABS showed that the tensile yield strength increases with an increase in the weight percentage of nylon-6. On increasing the SMA content from 2 to 8%, the tensile yield strength values improved considerably. However, the double extruded sample of nylon-6/ABS (70:30), with 5% SMA, showed a higher yield strength value than even the corresponding composition containing 8%



**Figure 7** Small angle light scattering patterns in the  $H_v$  mode for base polymers and their blends. Sample to film distance = 4.1 cm.

SMA, extruded once. The modulus value was high for the 50 : 50 nylon-6/ABS blend and the ternary blend with 5% SMA. In general, for a particular

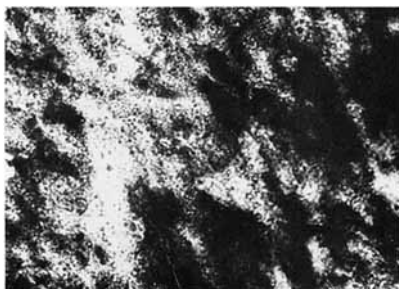
blend composition, when the tensile yield strength is high, then the modulus is low. The compatibilized blends were found to be ductile. The elongation to



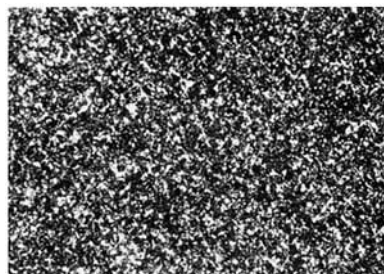
A



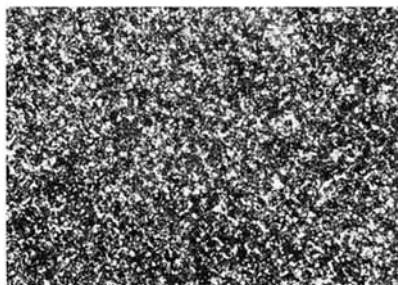
B



C



D



E

- A - NYLON-6
- B - ABS
- C - NYLON-6/ABS : 70/30
- D - NYLON-6/ABS : 70/30 WITH 5% SMA
- E - NYLON-6/ABS : 70/30 WITH 5% SMA  
( DOUBLE EXTRUDED )

100 μm

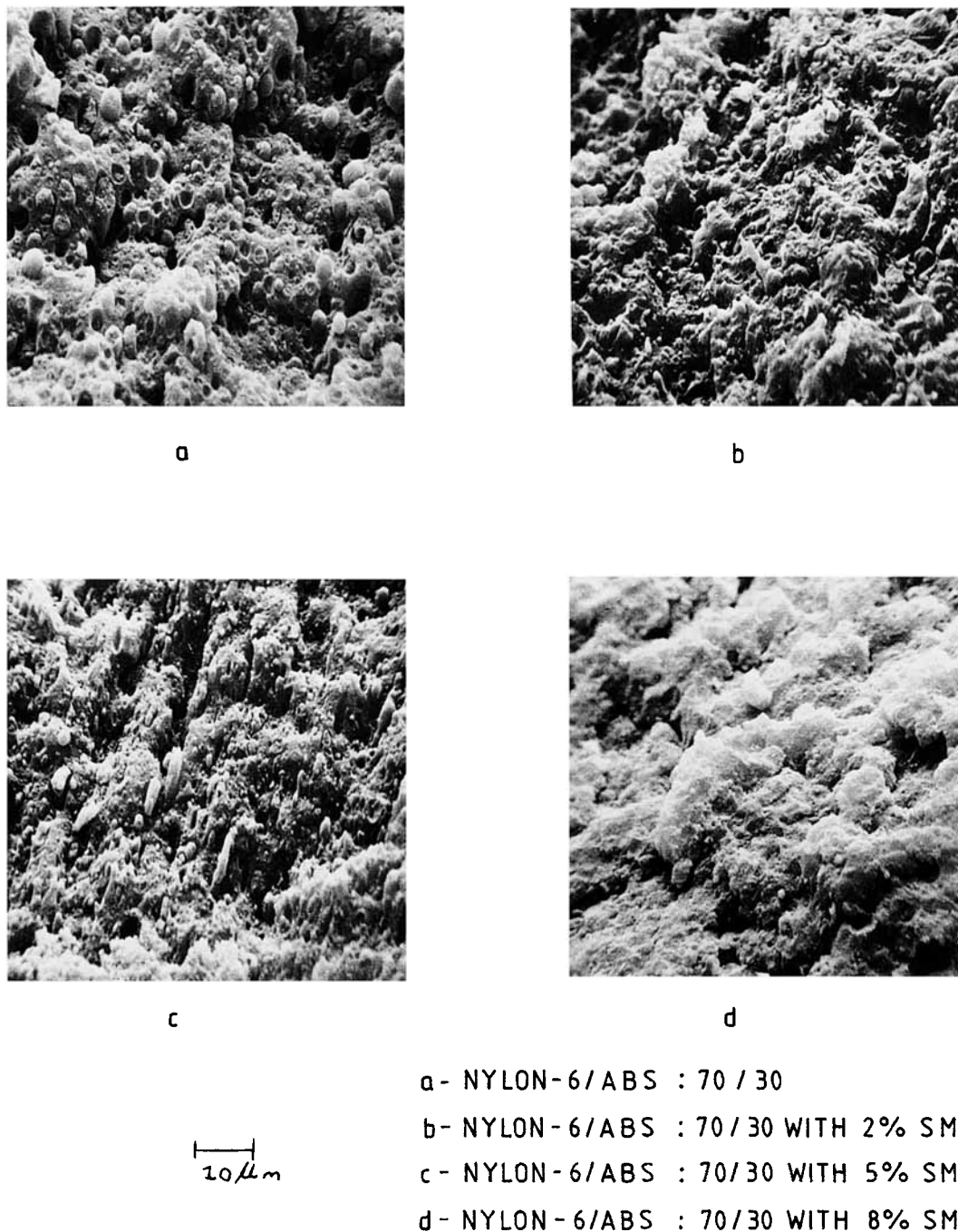
Figure 8 Optical photomicrographs obtained on a polarizing microscope.

break was higher for the compatibilized blends by a factor of 1.5, as compared to the uncompatibilized blends.

#### Morphological Studies

The  $H_v$  scattering patterns, obtained from SALS, were used to determine the shape, size, and nature

of the superstructures formed in these blends. In the present study, an SALS study has been performed for a particular system, namely for nylon-6/ABS of a 70 : 30 ratio, to see the effect of SMA on its morphology. The SALS patterns of pure nylon-6, ABS, and the 70 : 30 blend, with and without SMA, are presented in Figure 7. Pure nylon-6 shows a distinct, four-leaf clover-type pattern, with lobes



**Figure 9** Photomicrographs obtained on a scanning electron microscope.

at  $45^\circ$  to the polarizers. This pattern is characterized by a minimum intensity at the center and a maximum intensity along the scattering lobes, which is characteristic of scattering by spherulitic superstructures. Pure ABS shows no scattering, since it is completely amorphous in nature. The pattern for the blend of the 70 : 30 nylon-6/ABS without compatibilizer shows a four-lobe pattern, with lobes at

$45^\circ$  to the polarizers, and the pattern possesses a maximum intensity at the center, which decreases monotonically with an increase in scattering angle. The overall pattern is of lesser intensity as compared to that of pure nylon, which may be due to the low concentration of nylon-6, present at the region studied, indicating poor dispersion of the two phases. The addition of 5% SMA to this blend caused the

appearance of a four-leaf clover-type pattern, characteristic of spherulitic superstructures. The same sample, when extruded twice, showed a smaller four-leaf pattern, which indicates that the spherulites are bigger probably because of better mixing of the components. It is well known that the size of the spherulites is inversely proportional to the size of the  $H_v$  scattering pattern.<sup>9</sup> The formation of such structures, in the presence of SMA, might be due to two factors: (i) SMA, being a compatibilizer, improves the dispersion of both the phases, thereby making the blend more homogeneous<sup>7</sup> and (ii) SMA, being a rigid entity, might have provided nylon-6 with nucleating sites that resulted in better crystallization of nylon-6.<sup>14</sup>

Figure 8 shows the photomicrographs, obtained by polarizing microscopy, of the samples for which the SALS patterns were presented earlier. Pure nylon-6 shows a homogeneous and crystalline morphology, whereas pure ABS shows no such structure, since it is totally amorphous. The binary blend, containing 70 : 30-nylon/ABS, shows a two-phase morphology, in which the darker portions are due to ABS and the bright zones are due to the nylon-6 phase, indicating that these two components are incompatible and exist in two distinct phases. The addition of 5% SMA results in a homogeneous crystalline structure, similar to that of nylon-6, which implies better dispersion of the two components. The double extruded blend of the same composition also showed a similar structure.

The impact-fractured specimen surfaces were scanned using SEM at a magnification of about 2000. As seen in Figure 9, the 70 : 30 nylon 6/ABS blend shows a distinct phase separation, in which the minor component ABS exists in the form of globules. When 2% SMA was added to this blend, the size of the globules decreased. The addition of 5% SMA caused a further reduction of the globule size. With 8% SMA, the impact-fractured surface resembled that of a single phase. This kind of development in morphology can be attributed to the surfactant action of SMA,<sup>10,11</sup> which compatibilizes ABS and nylon-6 to form an alloy.

## CONCLUSIONS

Based on the above observations, the following conclusions have been drawn:

1. Polyamide-6 (nylon-6) and ABS form a two-phase, heterogeneous blend with little adhe-

sion between them. The addition of copolymer SMA improves the adhesion between the phases and consequently improves the mechanical properties of the blends.

2. Notched Izod impact, flexural, and tensile values improved with an increase in polyamide-6 content in the blend composition. However, unnotched Izod impact strength and modulus values seemed to have a decreasing trend with increasing nylon-6 content. However, upon the addition of SMA copolymer to the blend, the mechanical properties improved.
3. Both PM and SALS studies showed that SMA helped obtain better dispersion of the blend with greater homogeneity.
4. SEM provided further evidence, showing that SMA indeed acts as a compatibilizer for the polyamide-6/ABS system.

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