

# Polypropylene/Polystyrene Blends—Preliminary Studies for Compatibilization by Aromatic-Grafted Polypropylene

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**ABSTRACT:** The blends of Polypropylene (PP), that is a semicrystalline and nonpolar thermoplastic polymer with a polar and amorphous polymer such as Polystyrene (PS), are known to be immiscible. This article investigates the use of an aromatic vinyl monomer (AVM)-grafted PP (PPA) as a potential compatibilizer for such an immiscible blend system (PP/PS blend). PPA was prepared by grafting a monofunctional aromatic vinyl monomer onto PP using an organic peroxide at 180°C for 10 min in a Brabender mixer. Using a twin-screw extruder, blends of PP/PS in various composition containing different amount of PPA were prepared. Results obtained from tensile and impact strength, heat deflection, and melt flow index measurements shows some improvement in the properties of the blends indicating some compatibilization effects in the blend system. However, the scanning electron microscopy (SEM) micrographs strongly suggested a significant compatibilization between PP and PS. © 2001 John Wiley & Sons, Inc. *J Appl Polym Sci* 82: 428–434, 2001

**Key words:** aromatic vinyl; morphology; melt grafting; polypropylene/polystyrene blend

## INTRODUCTION

Development for new and interesting polymeric materials with complementary properties has recently intensified. One of the main directions of development of polymers with the aim of imparting specific desirable properties in modern polymer is through blending. Polymer blends are physical mixtures of structurally different homopolymer or copolymers. In the last decade, investigations on polymer blends have increased significantly.<sup>1</sup> There is no doubt that the main reason for blending is economy. A new polymer blend can be accomplished much more rapidly

than developing a totally new type of polymer. Nonetheless, polymer blending has several advantages. It can generate new materials with unique properties and good processability. It extends the performances of expensive resins and allows for quick modification of performances.

Most polymers are thermodynamically immiscible. Blending these components leads to a two-phase or multiphase morphologies.<sup>2</sup> Generally, in a two-phase morphology or system the major phase will form the continuous matrix and control most properties, while the minor phase will form dispersed morphological structures such as spheres, ellipsoids, fibers, plates, or ribbons, and contribute certain specialized or desired properties to the blend. However, immiscibility of two polymers leads to a material with poor mechani-

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cal properties due to phase separation in which the interface between polymers are very weak.<sup>3</sup>

This investigation attempted to improve the compatibility between PP and PS, which are known to be immiscible and incompatible<sup>4</sup> by the incorporation of an aromatic-grafted PP (PPA), as shown in Figure 1 as a compatibilizer. PPA was produced in our laboratory by grafting a mono-functional aromatic vinyl monomer (AVM) to PP.<sup>5</sup> In the compatibilization scheme (as shown in Fig. 2), it is expected that the PPA will act as an anchor at both sides of the interface where the PP component will provide good compatibility with polypropylene and AVM component would mix well in the styrene block. The success of this PP/PS blend system can serve as a model for the compatibilization of blends involving a semicrystalline and amorphous polymer.

## EXPERIMENTAL

### Materials

Isotactic polypropylene (Propelinas 200 D, MFI 2) and polystyrene (Poly-Star HH-30G, MFI 8.5) were supplied by Polypropylene Malaysia Sdn. Bhd. And Petrochemicals (M) Sdn. Bhd., respectively. Peroxide initiator Trigonox 101 (2,5-Dimethyl-2,5-di-*t*-butylperoxyhexane) was obtained from Akzo Nobel Chemicals. Acetone and xylene were obtained from Fluka and Merck, respectively. All reagents and materials used in this work were used as received.

### Grafting

The grafting of AVM monomer to polypropylene (PP) was performed in a Brabender mixer at 180°C with constant mixer speed (40 rpm) in the presence of a peroxide initiator, Trigonox 101. All samples were prepared based on 35 g of PP. PP was allowed to melt in the mixer and appropriate

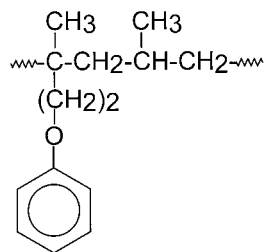


Figure 1 Structure of PPA.

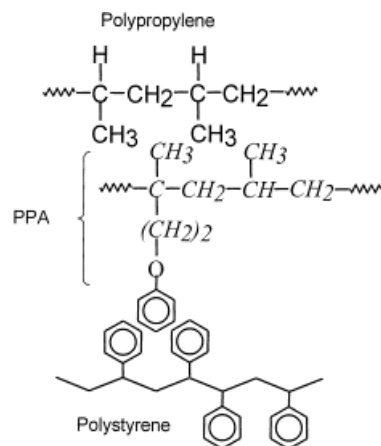


Figure 2 Compatibilization scheme of PP/PS by PPA.

amounts of AVM and peroxide initiator were added simultaneously. After 10 min the mixing was stopped and samples were collected and cooled.

### Extraction of Graft Polymer (PPA)

The crude graft PPA was dissolved in xylene to remove the unreacted monomer and initiator by refluxing for 4 h. After cooling to ambient temperature, acetone (100 mL) was added to precipitate the product. The resultant graft polymer was collected by filtration, washed with excess acetone and xylene ( $3 \times 200$  mL) to further enhance the removal of the residual monomer. The polymer was dried at 70°C in a vacuum oven for 7 h.

### Blending of PP/PS/PPA

The samples at desired composition (refer to Table I) were first dry mixed in a laboratory tumble mixer at room temperature, followed by melt blending in a Brabender DSK 42/7 twin-screw counter rotating extruder ( $L/D = 42$ ) at 200°C with the residence time of 5 min. Melt blending were done twice as to ensure homogeneity of blend. The extrudate was then palletized and injection molded into test specimens.

### Measurements of Mechanical Properties

Tensile test were carried out on Instron 5566 Universal Tensile Tester according to ASTM D638 with a crosshead speed of 50 mm/min. Notched Izod impact tests were performed on Ceast 6546 Pendulum Impact tester according to ASTM D256.

**Table I** Composition and Properties of the PP/PS/PPA Blends

| Sample      | Composition<br>(wt %) |     | Impact Strength<br>(J/m) | Tensile Strength<br>(MPa) | MFI<br>(g/10 min) | HDT<br>(°C) |
|-------------|-----------------------|-----|--------------------------|---------------------------|-------------------|-------------|
|             | PP                    | PPA |                          |                           |                   |             |
| PP20/PS80/0 | 20                    | 0   | 15.6                     | 33.4                      | 17.6              | 85.4        |
| PP20/PS80/2 | 20                    | 2   | 14.1                     | 33.0                      | 15.9              | 85.6        |
| PP20/PS80/4 | 20                    | 4   | 16.1                     | 32.7                      | 18.4              | 86.9        |
| PP20/PS80/8 | 20                    | 8   | 18.2                     | 32.3                      | 23.8              | 86.7        |
| PP50/PS50/0 | 50                    | 0   | 16.4                     | 30.8                      | 15.1              | 87.6        |
| PP50/PS50/2 | 50                    | 2   | 18.1                     | 33.5                      | 14.9              | 87.7        |
| PP50/PS50/4 | 50                    | 4   | 18.7                     | 31.7                      | 15.1              | 88.5        |
| PP50/PS50/8 | 50                    | 8   | 19.0                     | 32.9                      | 16.6              | 88.9        |
| PP80/PS20/0 | 80                    | 0   | 18.8                     | 29.2                      | 4.7               | 86.9        |
| PP80/PS20/2 | 80                    | 2   | 19.2                     | 29.6                      | 5.6               | 88.7        |
| PP80/PS20/4 | 80                    | 4   | 19.2                     | 29.5                      | 6.5               | 88.4        |
| PP80/PS20/8 | 80                    | 8   | 18.6                     | 29.3                      | 6.7               | 98.8        |
| Virgin PP   |                       |     | 25.8                     | 27.5                      | 12.7              | 84.0        |
| Virgin PS   |                       |     | 12.6                     | 36.4                      | 2.5               | 84.9        |

### Measurements of Heat Deflection Temperature (HDT)

HDT measurements were recorded using a Davenport Automatic HDT equipment at a heating rate of 120°C/h on a stress load of 0.45 MPa according to ASTM D648. Three specimens of each sample of dimension 127 × 12.7 × 3.2 mm were used.

### Measurement of Melt Flow Index (MFI)

MFI values were obtained by Zwick 4105 Melt Indexer. The test was conducted at 230°C using the load of 2.16 kg according to ASTM D1238.

### Scanning Electron Microscopy (SEM)

SEM was used to observe the morphology of blends. The experiments were performed on Philips XL 40 Scanning Electron Microscope. Samples used were fracture surfaces obtained from tensile and impact strength experiments. The samples obtained from impact test were etched by dipping specimens into tetrahydrofuran (THF) for 15 min at room temperature. The fractured surfaces were sputtered with gold before viewing.

## RESULTS AND DISCUSSION

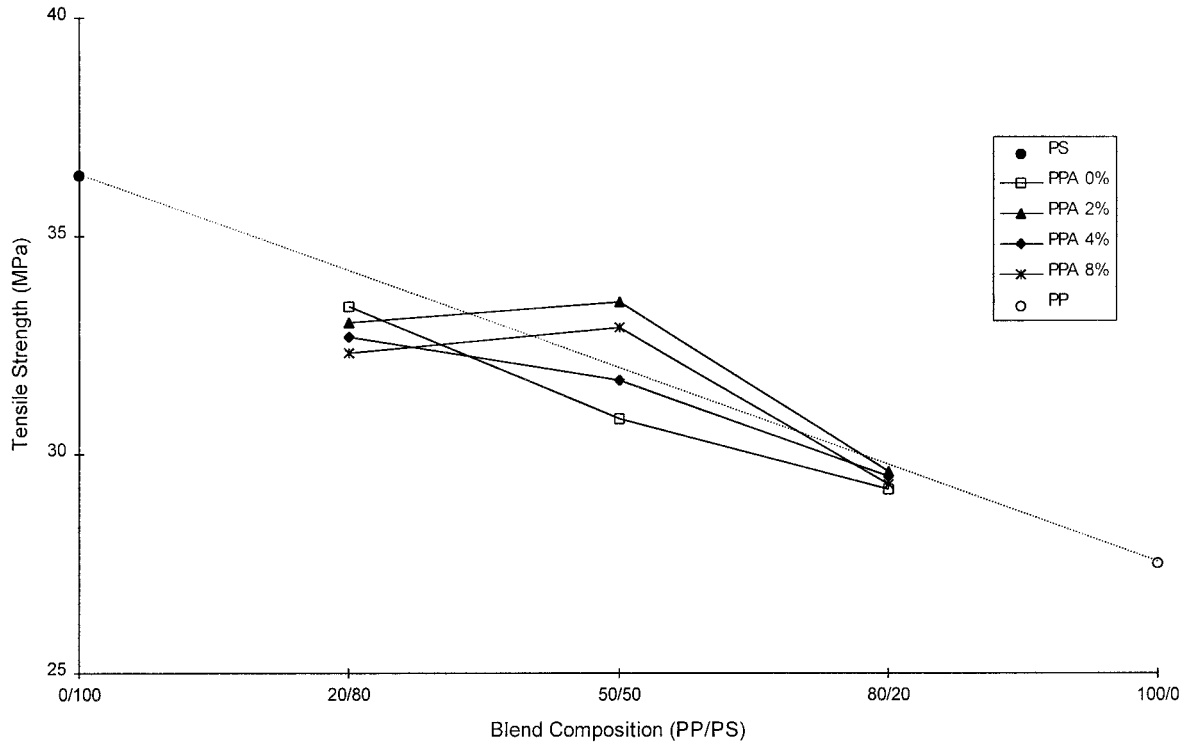
### Mechanical Properties

The tensile and impact strengths as a function of compositions are shown in Figures 3 and 4, re-

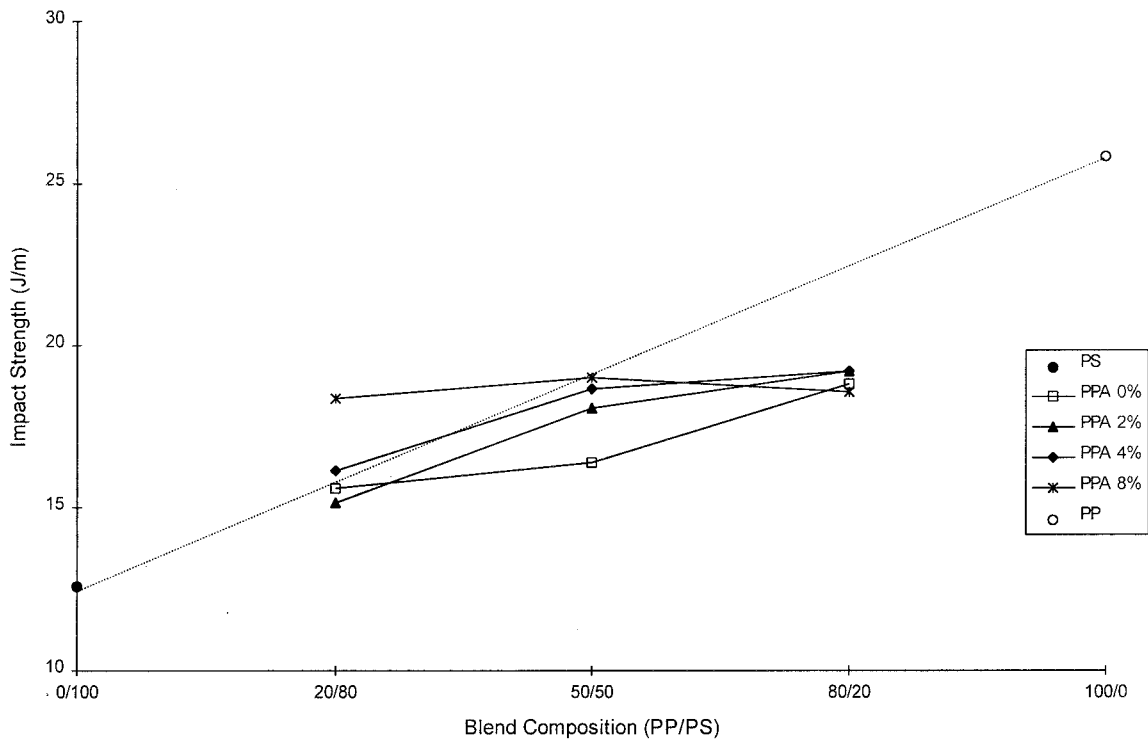
spectively. Results obtained generally show a small negative deviation from the simple additivity (dotted line in the figures); this arose from poor interfacial interaction due to incompatibility between PP and PS. Nonetheless, the tensile strength of the blends are higher than the virgin PP and some characteristic of additive behavior are shown in the PP50/PS50 and PP80/PS20 (PP-rich) samples. Conversely, in the impact properties, additive behaviors are found in the PS-rich samples, and the values of impact strength are higher than the virgin PS. The improvement in properties and the attribute of additive behaviour may be due to effects of some degree of compatibility, which more obviously showed in the morphology of blends as shown in Figures 7 and 8.

### Melt Flow Index (MFI)

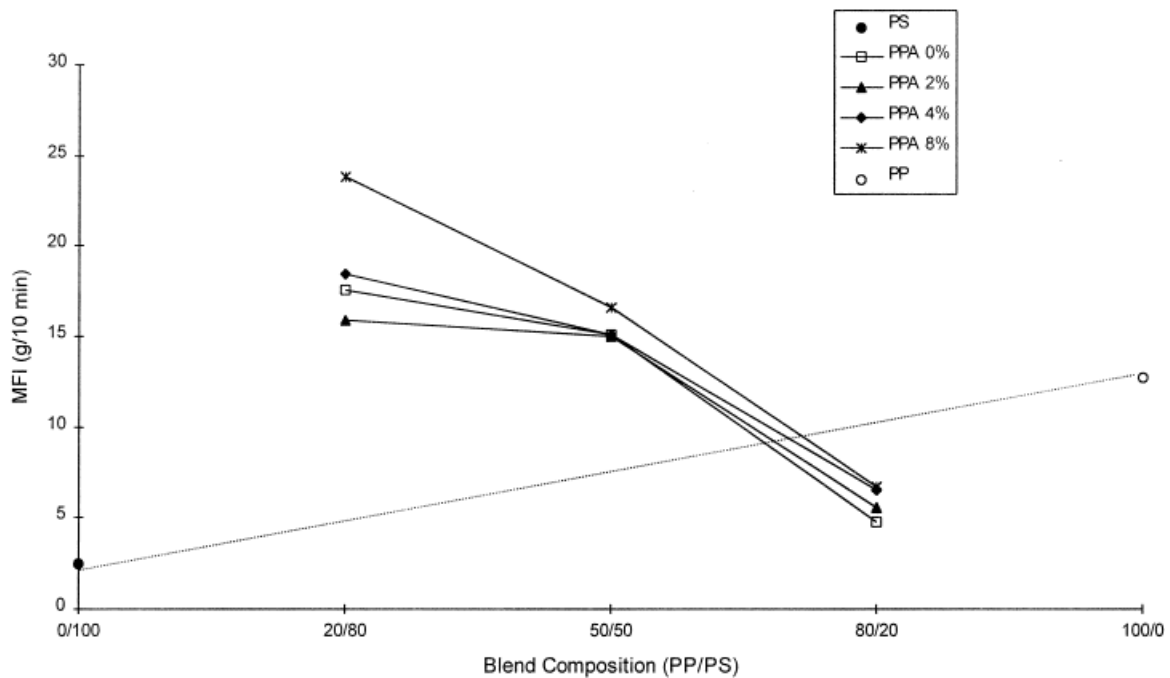
Figure 5 shows MFI as a function of composition. The result does not entirely represent the melt or flow properties, and certainly not designated as a rheological study of the blends but as an indication showing the influence of PPA on the melt index that can be related to the morphology of the blends. In the PS-rich blend, a synergistic effect was observed, PP as the dispersed domain appears to act as a flow promoter where high MFI values were recorded. The MFI increases as more PPA was added. On the other hand, the PP-rich blend shows a negative deviation of MFI values compared to the MFI of PP. This may be related to the morphology of blend as shown in Figure 8. The small brittle PS particles dispersed in a duct-



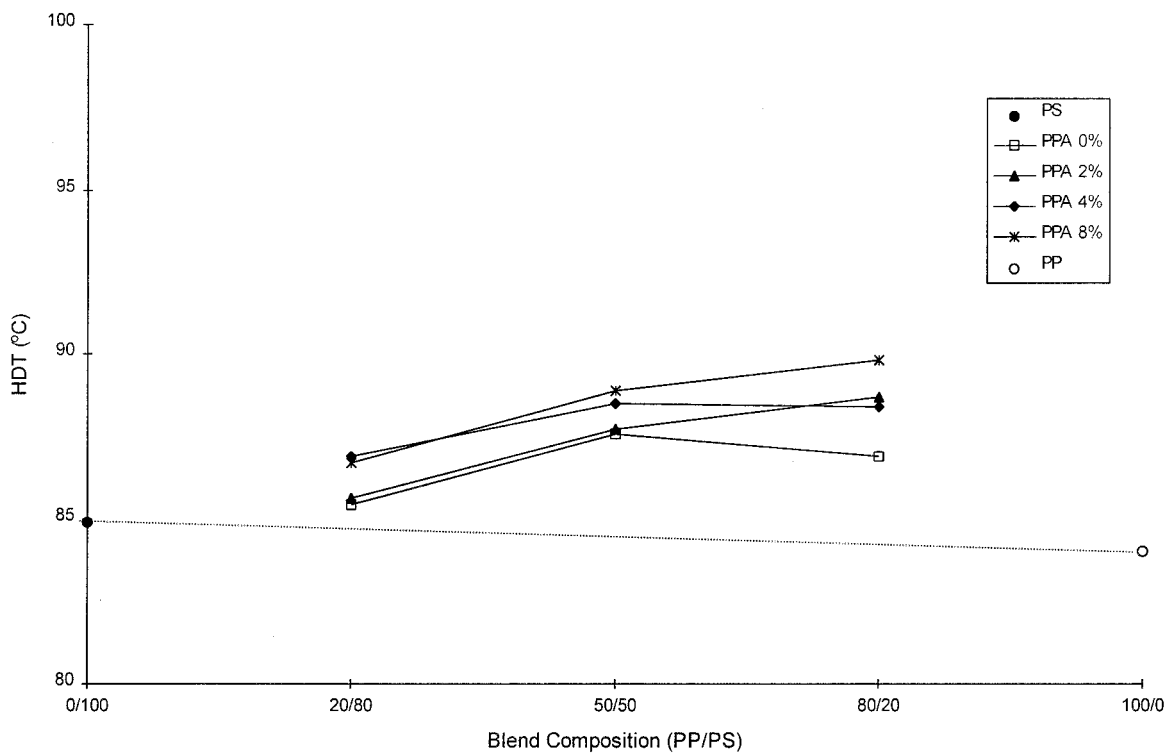
**Figure 3** Tensile strength vs. composition of PP/PS blends with variable percentages of PPA.



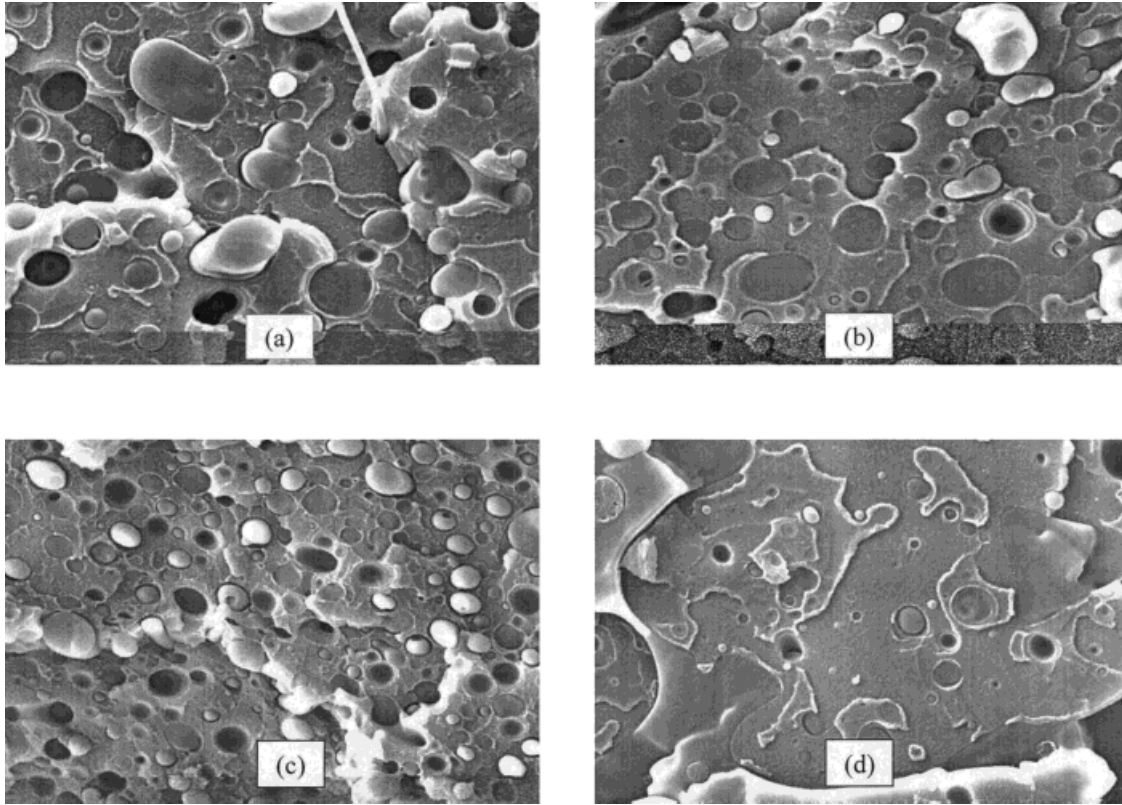
**Figure 4** Impact strength vs. composition of PP/PS blend with variable percentages of PPA.



**Figure 5** Melt flow index vs. composition of PP/PS blend with variable percentages of PPA.



**Figure 6** HDT vs. composition of the PP/PS blend with variable percentages of PPA.



**Figure 7** SEM micrographs ( $\times 2100$ , magnification) of PS rich samples (PP20/PS80) blends fractured (tensile specimens) with various percentages (%) of PPA: (a) 0%, (b) 2%, (c) 4%, and (d) 8%.

tile matrix seems to have a negative effect on the flow properties, which are dependent on the interparticle interaction and deformability of morphology.<sup>6</sup>

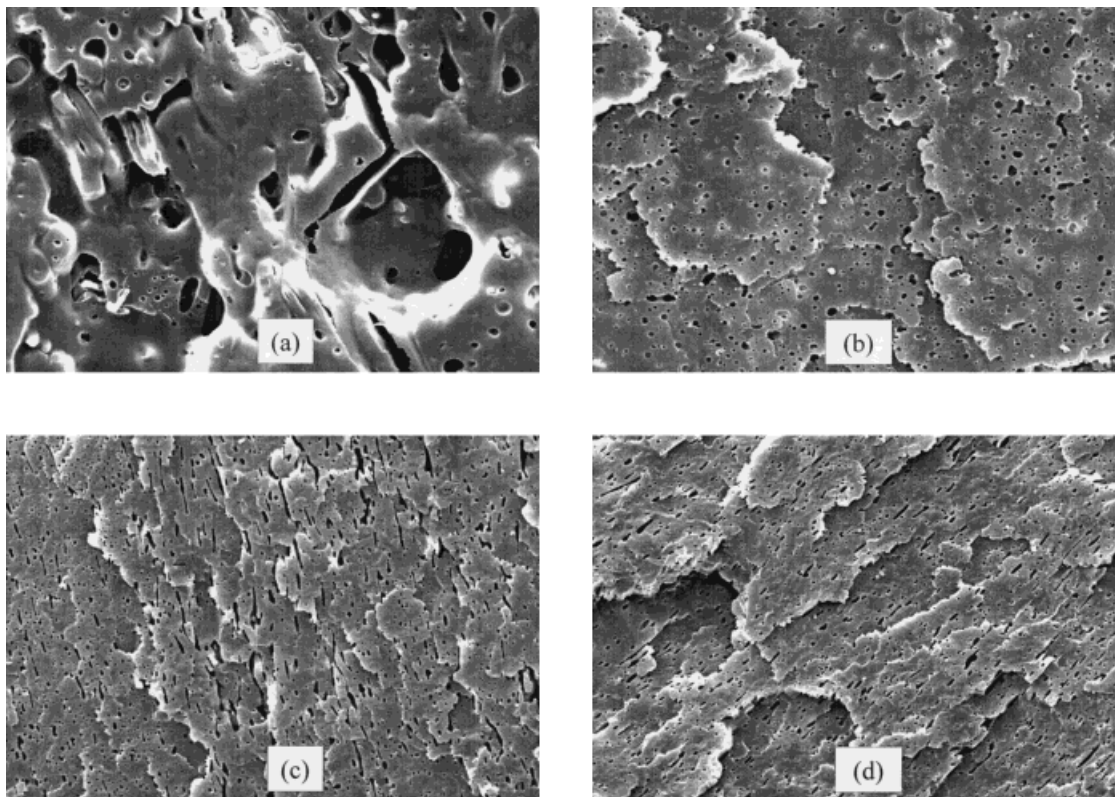
#### Heat Deflection Temperature (HDT)

Improvements in HDT values that exhibit a synergistic effect were observed in the blends. HDT increases with the increase of PP and PPA content in the composition of the blends as shown in Figure 6. All blend samples show a positive deviation of additivity for deflection temperatures that reflect some form of compatibility between the two polymers. The highest value achieved at 89.9°C noted for the PP-rich sample (PP80/PS20/8) containing 8% of PPA showed an increase of 5.8 and 4.9°C higher than PP and PS, respectively.

#### Morphology

The morphology of PP20/PS80 (PS-rich) and PP80/PS20 (PP-rich) blends were selected as ex-

amples to illustrate the effect of PPA on the compatibilization between polypropylene and polystyrene in PS-rich and PP-rich blends, respectively. SEM micrographs of PP20/PS80 as shown in Figure 7(a)–(d) shows that the particle size of the dispersed phase (PP) was reduced when the PPA was added. Generally, the reduction in particle size in the dispersed domain would indicate the effect of increase attraction between phase, thus improving compatibility.<sup>7</sup> The compatibilization of the blend was more apparent as illustrated in PP-rich (PP80/PS20) micrographs as shown in Figure 8(a)–(d). The micrographs of the specimen that does not contained any quantity of PPA [Fig. 8(a)] show a coarse and unstable particle structure, and an uneven distribution of the dispersed PS phase. This observation suggested an incompatibility that indicate low adhesion between the phases, giving rise to poor stress transfer across the interface.<sup>3</sup> While, through the addition of PPA, the particles are smaller, better dispersed, and was more evenly distributed in the PP matrix, indicating improvement in compatibility be-



**Figure 8** SEM micrographs ( $\times 350$ , magnification) of PP rich samples (PP80/PS20) blends fractured (impact specimens, etched) with various percentages (%) of PPA: (a) 0%, (b) 2%, (c) 4%, and (d) 8%.

tween Polypropylene and Polystyrene. However, the present of some debonded holes on fractured as shown in Figure 7 (unetched, PS-rich sample) indicate weak interfacial interaction between matrix and dispersed phase. This effect explained the occurrences of small negative deviations from the simple additivity rule in the properties of the blends.<sup>8</sup>

## CONCLUSION

Significant improvement in compatibilization of polypropylene (PP) and polystyrene (PS) was achieved through the use of an aromatic grafted PP. The evidences of compatibilization obtained from the morphological observations are consistent with those obtained from their physical and mechanical properties. However, continuous investigation especially on the rheological properties and crystallinity studies are necessary to successfully explore the true potential of such blends.

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