

Investigations on the Formation of Composites by Injection Molding of PA6 and Different Grafted Polypropylenes and Their Blends

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Received 29 December 2004; accepted 16 June 2005

DOI 10.1002/app.22983

Published online in Wiley InterScience (www.interscience.wiley.com).

ABSTRACT: Blends of different types of polypropylenes (PP) with polyamide 6 (PA6) were produced by extrusion. The PPs used were a PP homopolymer, a maleic anhydride-grafted homopolymer, and an acrylic acid-grafted homopolymer. The blends were characterized by DSC measurements, selective extraction, infrared spectroscopy, REM microscopy, melt rheology, and their mechanical properties. Three types of interactions in the blends as well as in two-component composites mold by the core-back process could be identified. Blends of PP with PA6 were not compatible, and two-component bars could not be produced. Blends of PPgAA and PA6 were made compatible during reactive extrusion. Two-component bars could be produced only with a blend containing 50 wt % PA6. The composite for-

mation was based on the interdiffusion of PA6 in both components and the reactive compatibilization in the blends. Blends of PPgMAN were also compatibilized during reactive extrusion. The composite formation on two-component injection molding was based on two mechanisms: the interdiffusion at sites, where PA6 chains of both the components came into contact, and an interfacial reaction, where PPgMAN and PA6 came into contact. The interfacial reaction was supported by the high mobility of the first component at the temperature of the melt of the second component. © 2006 Wiley Periodicals, Inc. *J Appl Polym Sci* 100: 2992–2999, 2006

Key words: polyamides; polyolefin; injection molding; composites; reactive processing

INTRODUCTION

Polyamide 6 (PA6) is widely used as a construction material in all fields of engineering, e.g., automotive, power, and mechanical engineering, because of its high mechanical strength, rigidity, and thermal stability. PA6 shows low permeations of organic vapor and liquids, e.g., petrol. Its good sliding properties open further fields of applications. It may be advantageous to combine the properties of PA6 with that of another polymeric material, for some uses, e.g., to increase the impact strength, reduce the cost, or to create a diffusion barrier toward water. Polypropylene (PP) is a suitable polymer with almost opposite properties of PA6. Because of the incompatibility of PA6 and PP, some compatibilization has to be established. The most effective way is the use of a PP grafted with acrylic acid or maleic anhydride as a blend component.¹ Grafting is realized in the molten² or in the solid

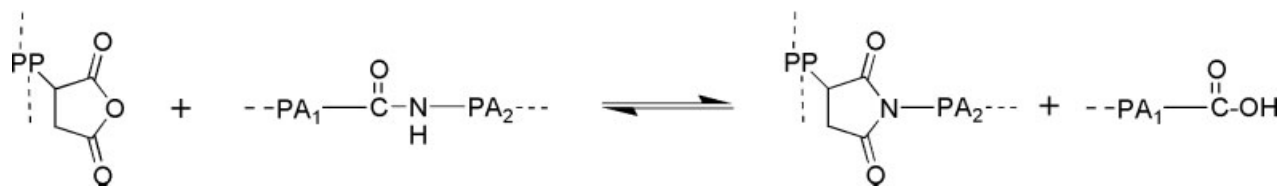
state.³ On reactive extrusion of the grafted PP and PA6, compatibilization is achieved by the formation of copolymers according to Scheme 1 in which the PA6 branches are bound via an imide bond.^{4–6} The reaction time, i.e., the residence time of the mixture in the extruder, is several minutes, and the reactions are carried out at high melt temperature.

Although the reactive blending produces materials with a combination of the good properties of the components, the disadvantageous properties are also combined.

A better approach is the production of parts having the components at that site at which their best properties can be exploited. Those parts may be formed by two-component injection molding, in which a second component is injected into a cavity, which is partly filled with the already solidified first component. For instance, one component may be used as the construction material and the other as the functional material that exhibits good surface or sliding properties. A combination of the pure PP and PA6 shall not be possible due to its incompatibility. At long residence times, a reactive coupling has been shown to be possible.⁷ For the injection molding process, however, the reactive coupling is limited by the very short residence time, which is in the order of a second. Thus, the

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Contract grant sponsor: The Deutsche Forschungsgemeinschaft (Vom Molekül zum Material); contract grant number: Lu451/13.



Scheme 1 Reaction of a maleic anhydride-grafted polymer with PA6.

composite formation is dominated by the short-time thermal behavior of the components at the interface. Previous works revealed for different systems that chemical reactions could be exploited to bind polymeric materials in the injection molding process even though the residence time at a high temperature is very short.^{8,9}

In this paper, we investigate the formation of composite parts with polyamide as one component and different types of PP as the other component. Also, blends of different types of PPs with PA6 are used to enhance the compatibilization. These blends of different types of unmodified, acrylic acid-grafted, and maleic anhydride-grafted PPs with PA6 are the subject of the investigations in the first section of the paper. Here, chemical reactions between the grafted PPs and PA6 are studied. In the second section, two-component injection molding investigations with these special blends are presented. Conclusions are drawn from the reactive behavior and the properties of the blends toward the composite formation, and three different types of interactions in the blends and in the composites are identified.

EXPERIMENTAL

The acrylic acid grafted-polypropylene was a Polybond 1002 from Crompton Corp. The content of acrylic acid moieties was 6% by mass or approximately 0.83 mmol g^{-1} . The melt flow rate was $20 \text{ g (10 min)}^{-1}$ at 230°C and 2.16 kg , as measured according to ASTM D 1238 standards. The maleic anhydride-grafted polypropylene Scona TPPP 2112 was supplied by Kometra, Germany. The content of maleic anhydride was 1.2% by mass, which equals 0.12 mmol g^{-1} . No free maleic anhydride was found by titration. A melt flow rate of $2.9 \text{ g (10 min)}^{-1}$ at 190°C was given. The PP homopolymer Moplen HF 500N was supplied by Basell. This product had a mass flow rate of $12 \text{ g (10 min)}^{-1}$ at 230°C and 2.16 kg (ISO 1133). Blends of one of the PP types and the PA6 type Ultramid B3 (BASF, Germany, melt flow rate = $130 \text{ cm}^3 \text{ (10 min)}^{-1}$ at 275°C and 5 kg with a water content of the PA6 less than 0.05%, according to ISO 1133) were produced by reactive extrusion using a twin-screw extruder with a screw aspect ratio of $L/D = 41$ and the following conditions: screw revolution rate = 100 min^{-1} , mass

rate = 10 kg h^{-1} . The temperatures at the zones were decreasing in the range between 240 and 205°C . The PPs were fed continuously gravimetrically as the main component. PA6 was added gravimetrically. The different blends produced had compositions of 0, 3, 6, 10, 20, 30, and 50% PA6 by mass (wt %).

The blends were extracted in formic acid according to the following procedure: 5 g of the ground sample was mixed with 100 mL formic acid and shaken for 24 h. The mixture was separated by filtration over a G4 frit. The residue was shaken three times with fresh formic acid for 4 h each and filtered again. This fraction was considered as nonsoluble residue in formic acid. The accumulated supernatant was poured into water to precipitate the dissolved polymer. The precipitate was separated by filtering with a G4 frit. This fraction was considered as soluble extract in formic acid. Both precipitates were finally washed with water until the filtrate was neutral.

The PP types, the PA6, and the blends were investigated under nitrogen by differential scanning calorimetry (DSC) using a DSC 7 device (PerkinElmer, Wellesley, MA). Heating and cooling rates for approximately 10 mg samples were 10 K min^{-1} . The curves were analyzed as follows: The glass transition temperature was taken as the average of the intersection points of the extrapolated lines before and after the transition, respectively, with the tangent at the point of return at the rising curve. Melting (T_m) and crystallization (T_c) temperatures were taken as the temperatures at the maximum peak heights. The heats were calculated from the areas taken from the curves as integrals between the onset points of the corresponding peaks. The heats were related to the masses of the components in the material according to their composition. FTIR spectra were recorded using a Bruker IFS66. Investigations of the melt rheology were done using an ARES rheometer from Rheometric Scientific Inc. (Epsom, UK), with a plate-plate configuration. The melt viscosity was measured at constant temperature of 250°C as a function of the shear rate. The temperature for Moplen HF 500N was 210°C .

For investigations on the bond strength between the blends and PA6, two-component bars were produced according to Scheme 2 with a core-back mold. The first component was injected in compartment A, whereas a core locked the other part of the mold. The first com-



Scheme 2 Sketch of the two-component tensile bar with indication of the gates.

ponent was allowed to solidify. After a delay time of usually 25 s, the core was removed and the second component was injected. The mass temperatures for both components were 260°C. The temperature of the mold was 45°C. The blends were dried for 10 h at 80°C prior to the molding. The bond strength was characterized by a tensile test according to ISO 527-2/1A/50 with a drawing rate of 50 mm min⁻¹, if composite samples could be produced. The interface in the two-component bars was investigated by removing the PA6 by selective extraction with formic acid. Hereby, no damage of the bars occurred. XPS spectra were recorded with an Axis Ultra spectrometer (Kratos Analytical Ltd., Manchester, UK).

RESULTS

Blend preparation and characterization

The details of the composition and specification of the bare polymers and of the blends are shown in Table I. For comparison with the blends, the bare PPs were also extruded to ensure the same thermal treatment.

TABLE I
Complete List of Materials Used and Their Compositions. The Tag Stands for the PA6 Content.

Label	Composition
PA6	Ultramid B3
PP	Moplen HF 500 N
PP-0	PP, extruded
PP-10	Blend of PP with 10 wt % PA6
PP-30	Blend of PP with 30 wt % PA6
PP-50	Blend of PP with 50 wt % PA6
PPgMAN	Scona TPPP 2112
PPgMAN-0	PPgMAN, extruded
PPgMAN-3	Blend of PPgMAN with 3 wt % PA6
PPgMAN-6	Blend of PPgMAN with 6 wt % PA6
PPgMAN-10	Blend of PPgMAN with 10 wt % PA6
PPgMAN-20	Blend of PPgMAN with 20 wt % PA6
PPgMAN-30	Blend of PPgMAN with 30 wt % PA6
PPgMAN-50	Blend of PPgMAN with 50 wt % PA6
PPgAA	Polybond 1002
PPgAA-0	PPgAA, extruded
PPgAA-3	Blend of PPgAA with 3 wt % PA6
PPgAA-6	Blend of PPgAA with 6 wt % PA6
PPgAA-10	Blend of PPgAA with 10 wt % PA6
PPgAA-20	Blend of PPgAA with 20 wt % PA6
PPgAA-30	Blend of PPgAA with 30 wt % PA6
PPgAA-50	Blend of PPgAA with 50 wt % PA6

These materials were marked with the tag “-0.” It was found in DSC investigations that the second heating scan was apparently different from the first scan, even for the bare materials. The differences between the second heating scan and the following heating scans were almost negligible. For that reason, only the second heating scans are discussed, if not stated otherwise.

The DSC curve for the heating of the blend PP-50 in Figure 1(a) exhibits a melting peak at 221°C, which is close to that value supplied by the manufacturer for PA6. The cooling curve shows a crystallization peak at 173°C. Super cooling and thermal inertia may have caused the lower melting point, compared with the crystallization point, since the heating and cooling rate was apparently finite. The super cooling effect may occur if the number of nuclei in a volume is low. The DSC curves in Figure 1(a) show also a melting point at 163°C, which is within the range given by the manufacturer, and a crystallization point at 123°C. These values were assigned to PP. Consequently, the thermal behavior of both blend components was independent from each other, and the components were immiscible.

The DSC curves of PPgAA-0 in Figure 1(b) show a melting peak at 163°C and a crystallization peak at 122°C. These values are close to those of PP [see Fig. 1(a)]. In the curve of PPgAA-50, a glass transition at 54°C was observed, which was assigned to PA6. This glass transition temperature was almost the same as that of PA6 in PP-50, which revealed the immiscibility also for PPgAA and PA6. At 163°C and 217°C, two endothermic peaks that were assigned to the melting peaks of PP and PA6, respectively, were observed. However, in the cooling curve of PPgAA-50, no crystallization peak of PA6 in its typical range was observed. An exothermic peak close to the crystallization temperature of PPgAA at 125°C arose. Its enthalpy is approximately the same as the sum of the melting peaks of both components. This indicates that a fractionated crystallization¹⁰⁻¹³ occurred in which the PA6 crystallization at its normal temperature was suppressed, and in which the PA6 starts to crystallize on the crystallization of PPgAA. The reason for the fractionated crystallization in this system is that PA6 formed a high number of small isolated domains in the melt that have not enough nuclei to crystallize.

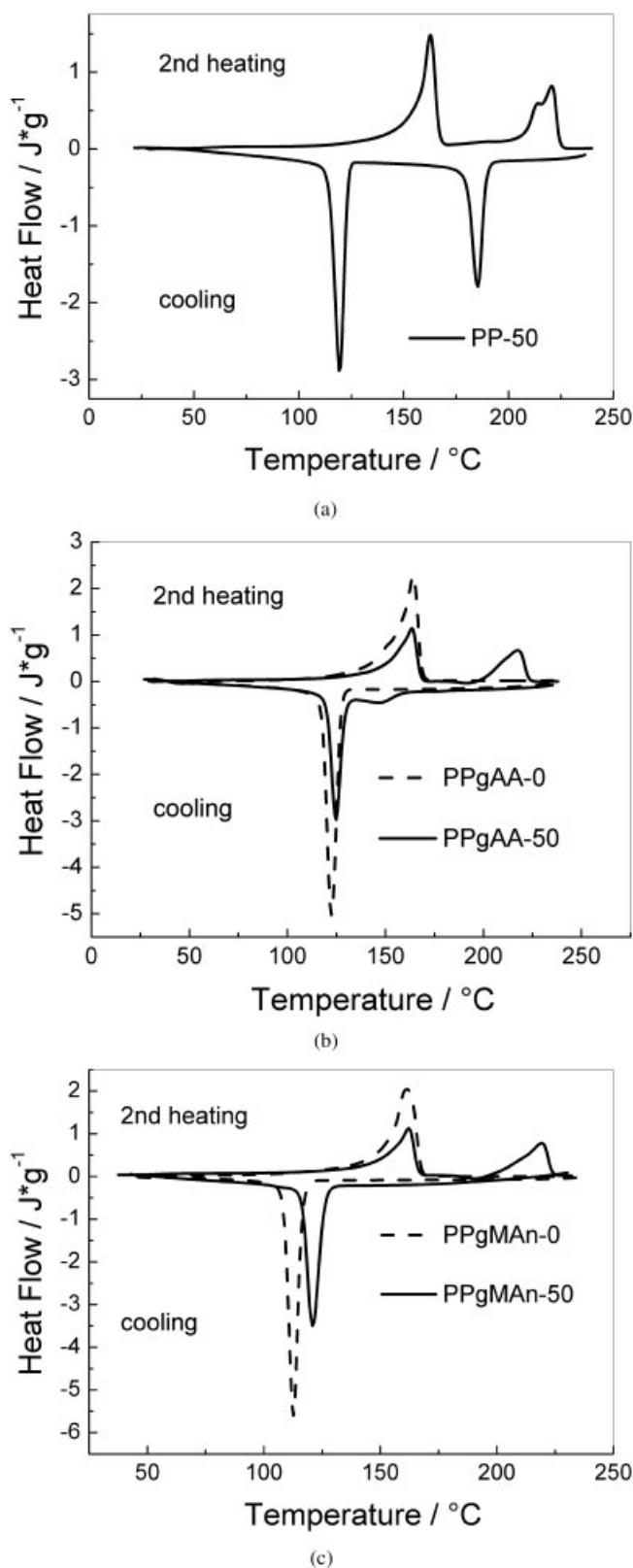


Figure 1 DSC curves of the blends. (a) PP-50, (b) PPgAA-0 and PPgAA-50, and (c) PPgMAN-0 and PPgMAN-50. Only the second heating and the cooling scans are shown.

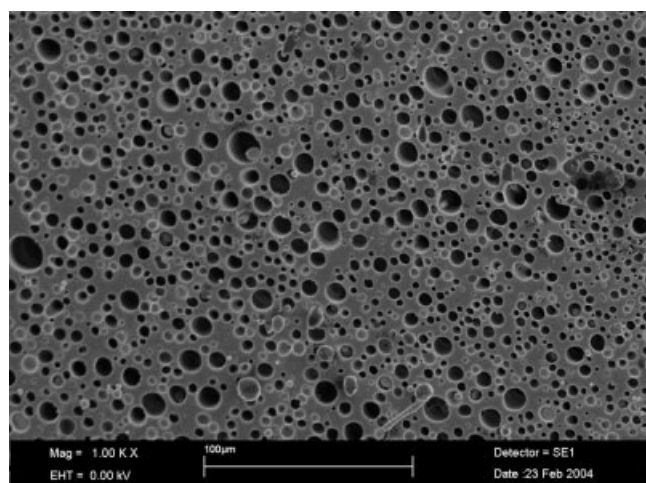
Therefore, super cooling occurred until the crystallization of PPgAA started, which produced the nuclei for the crystallization of PA6. The formation of small domains of PA6 in the PP matrix, essential for the fractionated crystallization, points to a compatibility of the components in the blend. Fractionated crystallization was also observed in all PPgAA blends with PA6 contents lower than 50 wt %. As shown in Figure 1c, the fractionated crystallization also occurred with PPgMAN-50.

The morphology was evaluated by microscopy images of samples, whose surfaces were etched with formic acid to dissolve the PA6. Thus, the dark areas in Figure 2 represent the domains of soluble PA6. The REM picture in Figure 2(a) shows rough domains of PA6 in PP-50. Those domains are characteristic for blends of incompatible polymers such as PP and PA6. The domains in the micrograph of PPgAA-50 [Fig. 2(b)] are much smaller than those of PP-50. The approximate size of observable domains is 1 μm . This points to a finer distribution of the components, as already concluded from the crystallization behavior in the DSC investigations. In the micrograph of PPgMAN-50 in Figure 2(c), the domains almost disappeared, although at higher magnification some domains could still be resolved. The fine structure in the micrograph of PPgMAN-50 points to a high level of compatibilization of the components due to the grafted anhydride function on PPgMAN. On the extrusion of PA6 with PPgAA and PPgMAN, copolymers of PP and PA6 were formed, which acted as compatibilizers. According to the REM investigations, this compatibilization effect was higher for PPgMAN.

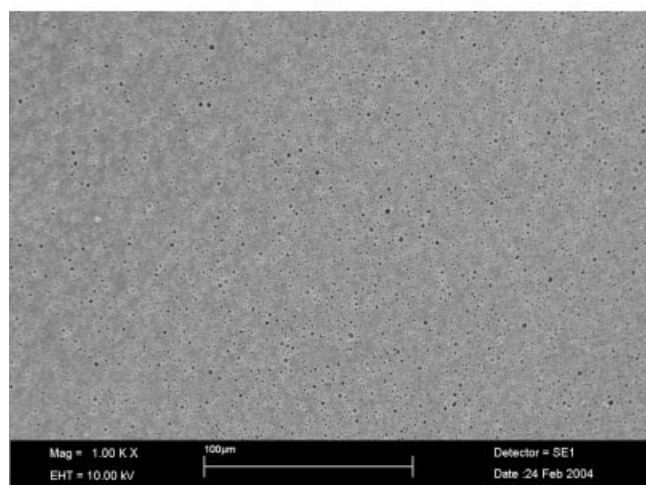
All blends were extracted in formic acid and extract and residue was investigated by infrared spectroscopy and DSC. Approximately 50 wt % of the PP-50 blend material could be extracted with formic acid, which suggested that all PA6 was dissolved quantitatively from PP-50. The nonextractable part of polyamide in the other blends, which is supposed to be bound in copolymers with PP via the grafted functional groups on PPgAA and PPgMAN, was calculated with eq. (1). Here m_0 is the total mass of PA6 in the blend according to its composition, and m_e is the mass of the extract.

$$\text{nonextractable PA6 content} = 1 - \frac{m_e}{m_0} \quad (1)$$

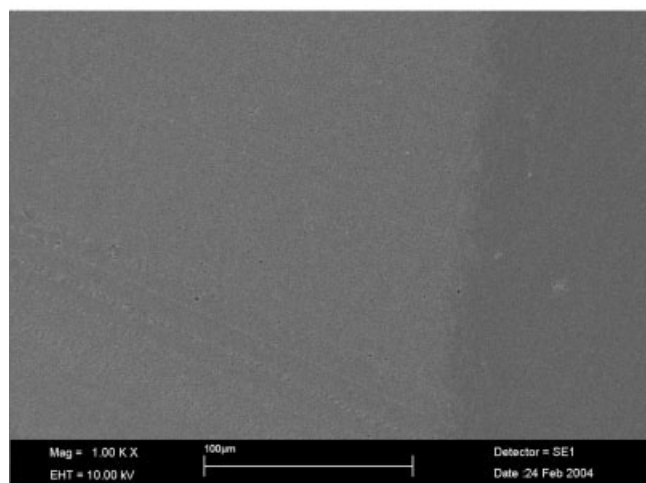
In Figure 3, the nonextractable part is shown as a function of the content of PA6 in the blends. The nonextractable parts of the blends with PA6 contents between 10 wt % and 50 wt % (samples PPgAA-10, PPgAA-20, PPgAA-30, PPgAA-50, PPgMAN-10, PPgMAN-20, PPgMAN-30, PPgMAN-50) depended only slightly on the composition and amounted to approximately 0.5 and 0.2 for the PPgAA and PPgMAN



(a)



(b)



(c)

Figure 2 REM micrographs of (a) PP-50, (b) PPgAA-50, and (c) PPgMAN-50. $\times 1000$ magnification. The cut surface was extracted with formic acid to remove the polyamide selectively.

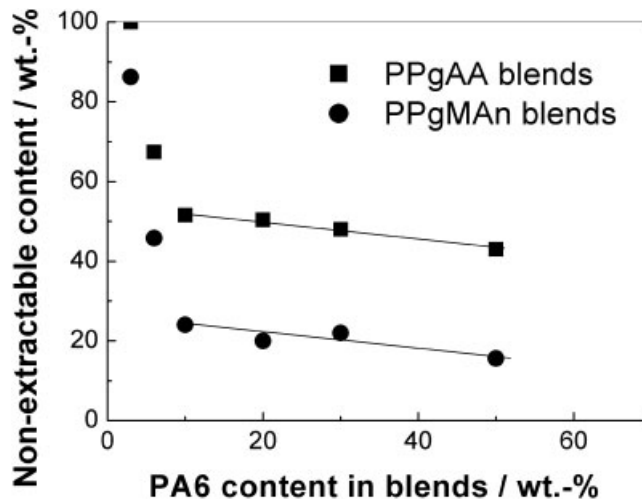


Figure 3 Nonextractable content as a function of the blend composition for blends with PPgAA and PPgMAN. The nonextractable content is the part of polyamide in the blend that was not soluble in formic acid. The nonextractable content of all PP-PA6 blends was zero.

blends, respectively. Thus, the amount of PA6 bound to the grafted PP was 2.5 times higher for PPgAA than for PPgMAN. Although the higher value for the PPgAA blends suggested a higher level of compatibilization, the REM micrographs suggested a better compatibilization of the PPgMAN blends. The higher value for PPgAA blends may be due to the higher content of acrylic acid grafted as compared with maleic anhydride grafted to PPgMAN. The molar content of acrylic acid in PPgAA was approximately 7 times higher than that of maleic anhydride in PPgMAN. The lower quantity of anhydride groups and the better compatibilization suggest that the efficiency of maleic anhydride to react with PA6 chains was higher.

The nonextractable content of the blends with a very small PA6 content (PPgAA-03, PPgAA-06, PPgMAN-03, and PPgMAN-06) was very high. It is not assumed that this high content represents the chemically bound part of polyamide but is rather caused by the nonaccessibility of small polyamide domains within the bulk blend.

FTIR spectra (not shown) of all extracts revealed that only the polyamide was extracted. No PA6 was found by infrared spectroscopy and DSC in the residue of PP-50 but in that of PPgMAN-50 and even more in that of PPgAA-50. In the latter, all the anhydride groups were completely reacted.

The $\log(G') - \log(\omega)$ function in Figure 4 is almost linear for the polymers investigated. The slope was approximately 1 for PP. An analog result was obtained for PPgMAN-0 and for the blend PP-50. PPgAA-50 was thermally not stable during the measurement procedure, so no data could be collected. The function for PPgMAN-50, however, exhibited a slope of 0.33. G' of

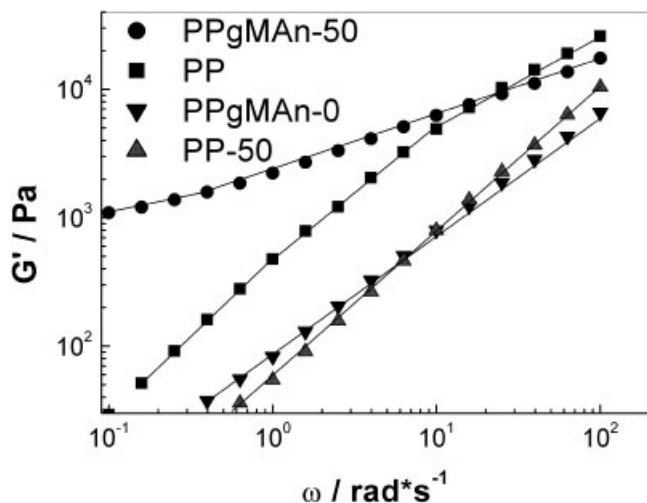


Figure 4 Storage modulus G' versus shear rate ω for different materials in a double logarithmic plot. 250°C. Moplen HF 500N at 210°C.

PPgMAN-50 at low shear rates was several orders of magnitude higher than that of the other polymers. Similar behavior was observed for PA6-(ethylene-propylene) rubber blends, in which the polyolefin was grafted with maleic anhydride.⁷ This behavior pointed to long chain branching or even a network structure in PPgMAN-50, in which the branches were formed by polyamide.

The investigations of the blends of PA6 with PP revealed that they are noncompatible in all compositions and even after treatment at the polyamide processing temperatures for a long residence time as used in the extruder. The blends with the grafted PP types were compatibilized by reaction of the PA6 with the grafted acrylic acid or maleic anhydride, respectively. This was shown by DSC and rheological investigations and by their morphology. Thus, there are probably domains of PA6 in a PP matrix, and some PA6 chains in the interface of the domains are covalently bound to PP chains in the matrix. In the next chapter, the composite formation between these blends and PA6 at two-component injection molding, where the residence time for establishing of bonds is very limited, is investigated.

Composite formation

Our investigations aimed at two-component injection molding with the blends that were produced in the first section of this paper. All composites were produced with PA6 as one component. The other component was one of the blends or a pure polymer, e.g., PP or PA6. The first component was allowed to solidify before the second component was injected. In all experiments, the mass temperatures of PA6 and that of

the other components were 260°C. The bond strengths of the composites were tested by a tensile test.

The composites with PA6 as first and PA6 as second component exhibited a high bond strength of approximately 40 MPa, as shown in Figure 5. This may be caused by attractive interactions and interdiffusion, since it may be assumed that the first component, though solidified, is heated over its glass transition temperature by heat exchange with the second component. The thermal conditions at the interface may be very important for the formation of a composite, as was already shown for a different polymer system,¹⁴ where an effective annealing of the first component on injection of the second component was found to be an important process. The mobility of polymer chains, as a requirement for interdiffusion and interchain contacts, depends on the difference of its temperature (the contact temperature) to a critical temperature, for instance the glass transition temperature or the Vogel-Fulcher temperature according to the Vogel-Fulcher law.

In the first series (Series I) of two-component injection molding experiments, PA6 was used as the first injected component and the blend or PP, respectively, as the second component. Since the first component had to be solidified on injection of the second component, its surface temperature on injection was estimated to be between the melting temperature of PA6 and the mold temperature, more probably near to the mold temperature. Composites with PP could not be produced, obviously because the components were noncompatible. Composites with all PP-PA6 blends as

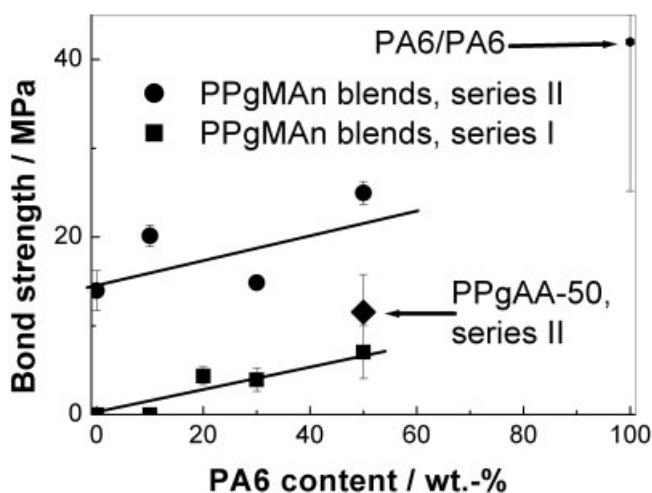


Figure 5 Bond strength of composites of PA6 with PPgMAN and PPgAA blends, respectively, as a function of PA6 content. Composites were produced in either sequence of the components. Data points of nonbonded composites are omitted for a clear presentation for PP, PP-PA6 blends, PPgAA-PA6 blends with PA6 being the first or second component. Error bars indicate the standard deviation. The added lines are linear fits.

second component could not be produced, even though the PA6 content in the blend was up to 30 wt %. Thus, even if an interdiffusion took place at the interface between the injected PA6 melt and the PA6 domains at the surface of the solidified blend, these domains had no adhesion to the PP matrix. This was already concluded from the blend investigations.

Composites could be produced neither with PPgAA nor with PPgAA-PA6 blends as second component, although the components in the PPgAA-PA6 blends were proved to be compatibilized, as it was concluded from the results of the investigations of these blends.

Composites with PPgMAN and PPgMAN-PA6 blends with a polyamide content of 3–10 wt % could also not be produced. However, composites could be produced with PPgMAN-20, PPgMAN-30, and PPgMAN-50. The bond strength increased with the PA6 content in the blend, as shown in Figure 5. Compatibilization between PPgMAN and PA6 in these blends was proved by extraction, REM, and by the mechanical investigations of the blends. Since composites could only be obtained with high PA6 contents in the blends, it may be assumed that an interdiffusion between the PA6 as first component and the PA6 domains in the blend at the interface was the dominant process for composite formation here. However, the bond strengths for those combinations were rather low.

In the second series (series II) of experiments, the blend or PP were used as the first injected component and PA6 as the second. As in the series I, no composites could be produced with PP, PP-10, PP-30 because of the incompatibility of the components PP and PA6.

As in the first series, composites of PPgAA and its blends with 10 and 30 wt % PA6 as first component and PA6 as second component could not be formed. However, the bond strength of the composite with PPgAA-50 as first component was high. It was shown in the REM and DSC investigations, that the PA6 in the blend domains was compatibilized by reactive extrusion. The composite may have been formed here only by interdiffusion between the PA6 injected and the PA6 in the blend domains at sites at which those are located on the outermost surface layer. One may assume that composite formation should also be possible with PPgAA-30 having a PA6 volume fraction of 25 wt %. It may be speculated that in the experiments of series I and in the experiments with PPgAA-10 and PPgAA-30 of series II, the PA6 domains in the blends were not accessible but screened by PP. In the experiments of series II, the mobility of the polymer chains at the interface was certainly higher than in series I, since the contact temperature was higher above the glass transition temperature of the PA6. The difference in the bond strengths with PPgAA-50 for both series of experiments clearly reveals the impact of processing conditions in the two-component injection molding process.

A totally different behavior was observed with PPgMAN and its blends in the series II experiments. The most obvious difference was that composites could be produced with PPgMAN-0 and PA6. The bond strength was approximately 13 MPa, as shown in Figure 5. The blend investigations showed that the PPs and PA6 were thermodynamically immiscible. As discussed in the experiments with PP-0, the components PP and polyamide are incompatible. Therefore, composite formation did not occur between the PP units and PA6. The content of MAN units in PPgMAN-0 was only about 1 wt %. A compatibilization only by physical interactions between the MAN unit as the polar group in PPgMAN-0 on the one side and the amide unit as the polar group in PA6 on the other would probably be too small to gain such a large effect. A reactive compatibilization, as occurred in the PPgMAN blends, may have taken place. Here, on reaction of the anhydride groups with amide groups during the short residence time at the injection, a link may be formed between the PP chain and the polyamide chain fragment. This chain link may be responsible for the strong enhancement of the bond between the components, even at such a small residence time at a high temperature. The interface between PPgMAN and PA6 was investigated spectroscopically at the PPgMAN side. Prior to the investigations, the soluble part of PA6 was removed selectively by repeated shaking with formic acid. ATR-IR spectra did not show significant signals of PA6 at the PPgMAN side of the interface. However, nitrogen and oxygen signals were detected by XPS measurements. The atomic concentration of nitrogen was approximately 5% by number of atoms. This is close to the concentration of nitrogen in PA6 (5.25%). The concentration did not change on further treatment with fresh formic acid. These investigations revealed that the PPgMAN is fully covered by a thin layer of PA6. Its thickness was larger than the information depth of the XPS measurements (some nanometers) but lower than that of the ATR-IR technique (some micrometers). These PA6 molecules must be bound chemically to the PPgMAN.

The composite formation between an amorphous polyamide and a maleic anhydride-grafted polypropylene, at contact times in the range from minutes to hours,⁷ revealed that the largest increase in interfacial fracture toughness took place at the beginning of the thermal treatment at temperatures above the melting temperature. This is the time range used for the preparation of composites by injection molding.

The bond strength, already high without PA6 in the blend, increased further with the PA6 content. The deviation of each data point from the fitted line added in Figure 5 is much larger than the error bar, which represents the standard deviation of the measurements on two-component bars. Thus, errors are still big. Nevertheless, a line was drawn to illustrate the dependence on the

PA6 content. The slope of this line roughly equals that of the experiments in series I with the PPgMAN blends. This increase may have the same origin as in the series I experiments that are interactions and interdiffusion between the PA6 domains in the blend and the PA6 of the other component. These interactions may be enhanced with increasing the PA6 content in the blend. Consequently, the bond formation in the experiments with PPgMAN blends in series II was a result of the reactive compatibilization via the anhydride group on injection molding plus physical interactions between the PA6 phases in both components.

Compared with the procedure in series I, the thermal conditions were different, although the components (PPgMAN, PPgMAN-PA6 blends, PA6) were the same. Since the melting temperature of the second component (PA6) was much higher than that of PP, the PP was effectively annealed or even re-molten, resulting in a larger mobility of chain segments at the interface. In contrast, the temperature in series I experiments was not sufficient to support a high mobility of the PA6 chains in the first component. As diffusion has a great impact on polymer reactions, the reactive compatibilization may have been supported by the molding procedure in series II experiments.

CONCLUSIONS

Blends of different types of PP with PA6 were produced by extrusion. The PPs used were a PP homopolymer, a maleic anhydride-grafted homopolymer, and an acrylic acid-grafted homopolymer. The blends were characterized by DSC measurements, selective extraction, infrared spectroscopy, REM, melt rheology, and their mechanical properties. Three types of interactions could be identified for blends and for composites produced by two-component injection molding containing PP, PPgAA, and PPgMAN.

It was shown that blends of PP with PA6 had poor mechanical properties. Their components were not compatible and could be separated quantitatively by selective extraction. Two-component bars could not be produced. Although an interdiffusion of the PA6 component and the PA6 in the domains of the blend may have occurred, the adhesion of the PA6 domains to the PP phase in the blend seemed to be poor.

Blends of PPgAA and PA6 were made compatible during reactive extrusion. The extraction investigations revealed that a large amount of the PA6 was bound chemically to the PP phase. The mechanical properties of the PPgAA could be improved by blending with PA6. This reveals good adhesion of PA6 to the PP phase. Composites with PA6 could only be produced with a blend containing 50 wt % PA6. Consequently, on injection of the PA6, only interdiffusion with PA6 in the blend may have occurred. These PA6 domains in the

blend were compatibilized, so that composite formation was possible. No interaction took place between the PA6 component and the PPgAA in the blend.

Blends of PPgMAN were also compatibilized during reactive extrusion. Their chemical and mechanical properties were very similar to those of the blends with PPgAA. An interdiffusion between the PA6 component and the PA6 domains in the blend was supposed to have taken place at the two-component injection molding, as in the case of the PPgAA blends. In addition, an interface reaction took place between PPgMAN and PA6, which resulted in the high bond strength of this composite. Thus, the composite formation of PPgMAN-PA6 blends as one component and PA6 as the other was based on two mechanisms: the interdiffusion at sites, where PA6 chains of both the components came into contact, and an interfacial reaction, where PPgMAN and PA6 came into contact. Since the bond strength increased with the PA6 content in the blend, the first process was apparently more efficient. The high bond strength in the cases where the PPgMAN blends were the first component and PA6 the second may be a result of the higher mobility of the chain segments of the first component on injection of the second. The reactivity of the grafted maleic anhydride was sufficiently high to react at the short time at which the high temperatures were present, whereas the reactivity of the grafted acrylic acid was not high enough.

The authors thank Dr. Roland Vogel for helpful discussions, Mrs. Gudrun Adam, Mrs. Uta Reuter, Mrs. Angelika Endres for sample characterization, and Mr. Andreas Scholze and Mr. Ralf Grafe for sample preparation.

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