

The Influence of Molecular Weight and Tacticity on Thermal, Morphological and Mechanical Properties of Ziegler – Natta Catalyzed Isotactic and Syndiotactic Polypropylene Blends

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crossref <http://dx.doi.org/10.5755/j01.ms.22.3.9056>

Received 05 January 2015; accepted 17 May 2015

The thermal, morphological and mechanical properties of polypropylene blends as influenced by the molecular weight and tacticity were investigated. Polypropylene sample blends (50/50 wt.%) were injection moulded into standard disks for morphological and mechanical tests. The thermal properties of the polypropylene blends were measured by differential scanning calorimetry (DSC), while the morphological and mechanical properties of specimens were investigated by means of optical microscope (OM), scanning electron microscopy (SEM), microhardness (MH) and dynamic mechanical analysis (DMA). DSC results of the bulk crystallization of the various isotactic polypropylene blends showed one melting peak, which indicates that cocrystallization of the blends occurred. However, the crystallization behavior of the polymer blends was strongly affected by the configuration (tacticity) and molecular weight of the polypropylene polymers. In addition, the MH and DMA measurements showed that blends of two different isotactic polypropylenes presented MH and storage modulus values between the values of the respective two MH and storage modulus values of the homopolymer samples, which in turn, depended on the type and degree of the crystallinity of the blends. However, the presence of syndiotactic polypropylene in a blend with isotactic polypropylene leads to a decrease in the MH value of the isotactic polypropylene samples.

Keywords: mechanical property, molecular weight, morphological property, polypropylene blend, tacticity.

1. INTRODUCTION

Polypropylene is one of the most widely used commercial polymers today. Its good mechanical properties and low price results in the continuous growth of its production and the expansion of its market. Its continuously increasing application accelerates research in all correlated areas, including the preparation of isotactic polypropylene based composites and blends [1]. The mechanical and physical properties of polypropylene are affected by a number of factors. The mechanical properties of the majority of polypropylene polymers are, apart from the processing conditions, influenced by their rheological and crystallization behavior. The degree of crystallinity is considered to be the most significant property influencing the physical and mechanical properties of a polypropylene sample [2–4]. An increase in crystallinity is often associated with an increase in properties such as the stiffness or modulus of a sample, while other factors, such as the impact strength, generally decrease with increasing crystallinity. The effects of molecular weight [5, 6], molecular weight distribution [7] and tacticity [8, 9] on the crystallization have been investigated by several authors.

Polymer blends have received much attention for many decades. Their morphology, crystallinity, microstructure, melting and crystallization behavior are

strongly dependent on the blend components [10–12]. The preparation of polymer blends is an important way to modify the target properties of individual polymers according to the requirements of the applications. Isotactic polypropylene based blends have been widely studied [13, 14]. Blends of isotactic polypropylene and syndiotactic polypropylene have also been widely studied due to the fact that syndiotactic polypropylene exhibits good mechanical and optical properties [15, 16]. This depends on the syndiotactic degree and the average molecular weight of the syndiotactic polymer in the blend. These blends of isotactic and syndiotactic polypropylenes can compete with polyethylene terephthalate (PET) and polyvinyl chloride (PVC) for packaging applications [15]. However, the morphology of the blends is widely influenced by the crystallization kinetics, and although crystallization of isotactic and syndiotactic polypropylene always occurs separately, phase separation cannot be observed by microscopy [15].

The aim of this study is to display the structure–property relationships of isotactic and syndiotactic polypropylene blends. The effect of molecular weight on the thermal, morphological and mechanical properties of isotactic and syndiotactic polypropylenes has previously largely ignored in similar studies. This study investigating the effect of molecular weight and tacticity on the thermal, morphological and mechanical properties of isotactic and syndiotactic polypropylenes blends. The thermal, morphological and mechanical properties of different

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polypropylene blends were investigated by means of differential scanning calorimetry (DSC), optical microscope (OM), scanning electron microscopy (SEM), microhardness (MH) and dynamic mechanical analysis (DMA) to demonstrate the effect of isotacticity and molecular weight on the properties of different polypropylene blends.

2. EXPERIMENTAL

2.1. Materials

Isotactic polypropylene polymers with different molecular weights and tacticities (indicated as PP1–PP10 in Table 1 and Table 2) were prepared in our lab using a suitable Ziegler-Natta catalyst. Propylene was obtained from Sigma-Aldrich and used without any purification. High purity argon and hydrogen were obtained from Afrox (South Africa). Toluene (Sigma-Aldrich) was dried by refluxing over sodium/benzophenone and then distilling under an inert gas atmosphere. Triethylaluminum (TEA) was obtained from Sigma-Aldrich. A commercial Ziegler-Natta catalyst with 2.78 wt.% Ti content was purchased from Star Chemicals & Catalysts Co. (China). The external donor (ED), diphenyl dimethoxysilane (DPDMS) and methylphenyl dimethoxysilane (MPDMS) were obtained from Fluka and used as received. Potassium permanganate, phosphoric acid and sulphuric acid were obtained from Sigma-Aldrich. A commercial syndiotactic polypropylene sample (indicated as SPP in Table 1 and Table 2) was obtained from Sigma-Aldrich and was used as received.

2.2. Polymerization procedure

The polymerization reactions were carried out in a 350-ml stainless steel Parr autoclave with a gas inlet and pressure gauge. The reactor was loaded with the catalyst (43 mg, Ti content 2.78 wt.%), TEA (2 mmol, Al/Ti mole ratio 80) and ED (0.091 ml in the case of DPDMS and 0.072 ml in the case of MPDMS, Al/Si mole ratio 5) in toluene (25 mL). The catalyst solution was stirred for 5 min and then the propylene was added. The reactor was pressurized with hydrogen and stirred for 1 h at room temperature. The reaction was then quenched by the addition of 10 % HCl/MeOH solution. The resulting polymer was filtered off, washed several times with methanol, and subsequently dried under vacuum at 80 °C for 15 h, to yield about 3–5 g of polypropylene as a white powder. Characterization data for all the samples are given in Table 1.

2.3. Preparation for morphological and mechanical tests

Test specimens were injection moulded into standard disks for morphological and mechanical tests with a HAAKE MiniJet II injection moulder. The injection moulding temperature was 190 °C and the injection pressure was 200 bar. The dimensions of the standard disks were 20.0 mm in diameter and 1.5 mm in thickness.

2.4. Preparation of etching reagent

Permanganic etching of polyolefins was used to prepare samples for studying the morphology. This

technique has been used in several studies involving polyolefins [12]. Potassium permanganate (1 g) was dissolved in 100 mL of a concentrated solution of 33 vol.% phosphoric acid and 67 vol.% sulphuric acid. The solution was prepared by adding potassium permanganate very slowly to the beaker containing both acids, with rapid agitation. After adding all the potassium permanganate, the beaker was closed and the contents stirred until all the potassium permanganate was dissolved (giving a dark green purple solution). All polypropylene samples were etched at room temperature.

2.5. Etching procedure

Specimens from each polymer, with approximate dimensions of length 10 mm, width 5 mm and thickness 1.5 mm, were cut from the disks prepared by injection moulding. Each sample was immersed in about 10 mL of the etching reagent in a beaker for a period of 60 minutes. This permanganic acid solution preferentially etches the amorphous part of the polymer in the spherulites in such a way that the lamellae then appear clearly. Subsequently, the specimens were carefully washed with hydrogen peroxide, distilled water and acetone, in order to avoid any artifacts caused by pollution effects. Samples were finally dried in a vacuum oven at 45 °C for 5 h.

2.6. Methods

The melting points and the degree of crystallinity were determined on a TA Instruments Q100 DSC. Three cycles were performed for each sample. The samples were heated in crimped aluminum pans from –30 °C to 220 °C at a rate of 10 °C/min. Samples were then cooled from 220 °C to –30 °C. Finally, the samples were heated for a second time at a rate of 10 °C/min to 220 °C. This was done to determine the peak melting temperature, T_m , from the peak maximum of the second heating cycle.

Weight average molecular weight and molecular weight distribution (MWD) were obtained by high-temperature gel permeation chromatography (HT-GPC). Samples were analyzed with a PL-GPC 220, using a flow rate of 1.0 mL/min and a differential refractive index (RI) detector. The analyses were carried out in 1,2,4-trichlorobenzene (TCB) stabilized with 0.0125 % 2,6-di-tert-butyl-4-methylphenol at 140 °C. The calibration was done with monodisperse polystyrene standards (EasiCal from Polymer Laboratories).

Nuclear magnetic resonance analysis (^{13}C NMR) spectra were recorded at 120 °C on a 600 Varian Unity Inova NMR spectrometer equipped with an Oxford magnet (14.09 T), operating at 600 MHz, using a 5 mm inverse detection PFG probe. Samples (60–80 mg) for ^{13}C NMR analyses were dissolved at 110 °C in a 9:1 mixture of TCB and benzene- d_6 (Bz_6).

A Zeiss Axiolab OM (magnification \times 50–100 μm) with a high resolution camera, CCD-IRIS (Sony), was used to examine the etched disks and investigate the crystal structure at room temperature under reflective light conditions. The disks of different polypropylene polymers used for OM test were obtained using a HAAKE MiniJet II injection moulder at 190 °C and 200 bar.

SEM analysis of etched disks was performed using a Leo® 1430VP scanning electron microscope operated at

15 kV of acceleration voltage at room temperature. All the surfaces to be studied were coated with gold under vacuum in order to eliminate any undesirable charge effects during the SEM observations.

Samples for compressive DMA were analyzed using a Perkin Elmer DMA 7e calibrated according to standard procedures. The samples were first melted at 180 °C for 8 minutes and then melt pressed at 180 °C and 5 MPa pressure. The samples were analyzed using a 5 °C/min heating ramp with an applied force oscillating at a frequency of 1 Hz. The static force was kept constant at 110 % of the dynamic force. The temperature range analyzed was between – 40 °C and 230 °C.

MH measurements were conducted on a UHL microhardness tester equipped with a Vickers indenter. Measurements were obtained using an indentation speed of 25 $\mu\text{m/s}$ and a dwell time of 15 s. Samples were analyzed at indentation loads of 10 gf. Ten measurements were recorded for each sample analyzed.

3. RESULTS AND DISCUSSION

3.1. Thermal properties

The thermal properties of polymer blends are a strong function of the blend morphology. This morphology and the associated phase behaviour strongly depend on the cocrystallization between the components of the blend. Blending also allows us to determine the effect of the molecular weight and tacticity on the crystallinity of the new materials. The manner in which materials crystallize affects the morphology, which has a significant effect on the properties of the material.

3.1.1. Effect of molecular weight

Table 1 presents data for the individual polypropylene polymers as well as data for the blended polymers. The polymers (PP7 and PP8) and (PP7/PP8) blend (50:50 wt.%) given in Table 1 were selected based on their differences in molecular weight and similarities in tacticity. DSC scans of individual polymer samples PP7 and PP8, and their blend (PP7/PP8) are presented in Fig. 1.

The blend showed only one melting peak (although the melting temperature is lower than that of the higher molecular weight material), even though the polypropylene sample PP7 has two melting peaks. This indicates that cocrystallization of the blend probably occurred. However, although a single melting peak of a blend is usually associated with a high extent of cocrystallization, two broad overlapping distributions of thicknesses of separate crystals, one from each component, could also lead to single broad peaks [17, 18]. In addition, results from other studies indicated that the linear growth rate of crystals markedly decreases with increasing molecular weight [6], but the overall crystallization rate might increase because an increasing number of intramolecular folded-chain nuclei could result in a higher nucleation density [19]. The above results, however, indicate that molecular weight above 10 000 g/mol appears to play role in the crystallization of this blend in the bulk. In a previous study, Wild et al. found that the molecular weight only has an effect on crystallization of polypropylene at low molecular weights (<10 000 g/mol) [20].

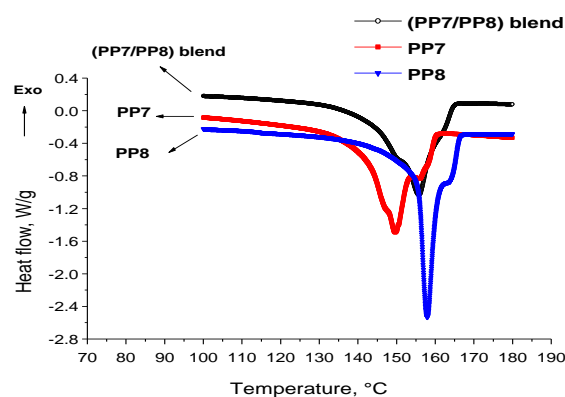


Fig. 1. DSC thermogram of a blend of selected polymers with the same tacticity but different molecular weights produced using heterogeneous catalysts

3.1.2. Effect of isotacticity

Fig. 2 shows the DSC scan of a blend of two polymer samples (PP6 and PP7) selected based on the differences in their tacticity and similarities in their molecular weight. The melting temperature of the (PP6/PP7) blend appeared to be influenced more by the material with the lowest tacticity (sample PP6 in Table 1 and Fig. 2).

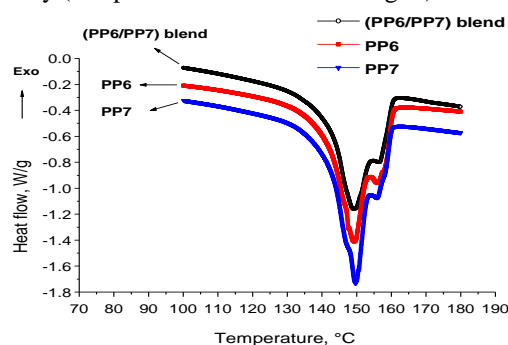


Fig. 2. DSC thermogram of a blend of selected polymers with similar molecular weights but different tacticities, produced using heterogeneous catalysts

Table 1. Characterization data of the polypropylene blends and fractions

Samples	M_w^a , g/mol	MWD	$mmmm^b$, %	T_m , °C	ΔH_m , J/g	X_c , %
PP1	252 956	5.4	94.0	160.6	103.9	50.0
PP2	312 580	4.1	96.0	161.9	108.9	52.0
PP3	215 397	5.9	86.0	157.5	90.5	43.0
PP4	195 693	4.3	98.0	160.0	119.7	57.0
PP5	207 823	2.9	96.0	161.0	103.2	49.0
PP6	28 270	2.4	84.0	148.9–158.7	83.7	40.1
PP7	25 918	2.4	93.0	149.5–158.3	87.1	41.7
PP8	92 596	3.5	93.0	157.9	110.1	52.7
(PP4/PP5) blend	–	–	–	160.2	91.5	44.0
(PP6/PP7) blend	–	–	–	148.5–158.7	76.0	36.4
(PP7/PP8) blend	–	–	–	155.8	96.1	46
SPP	174 000	2.3	93.0 ^c	111.9–126.5	33.3	15.9

^a determined by GPC; ^b determined by NMR; ^c syndiotacticity (rrrr %)

These results are in agreement with previous results obtained by other studies [8–10]. They found that

polypropylene blends with similar molecular weights and different tacticities showed an increase in linear crystal growth rate by three orders of magnitude when the isotacticity (*mmmm* %) of isotactic polypropylene increased from 78.7 to 98.8 % [8, 10].

The appearance of double peaks in the samples in Fig. 2 could be due to recrystallization processes [21, 22]. Recrystallization can usually be excluded by employing the DSC method with a wide range of heating rates, as shown in Fig. 3. The results in Fig. 3 show that the recrystallization occurs to a considerable degree only at heating rates lower than 10 °C/min. For heating rates greater than 10 °C/min recrystallization on scanning does not have time to occur and determination of the effective ΔH_m and T_m of the samples becomes possible. Although these are only preliminary results, indications are that there are two variables that influence cocrystallization in the bulk: molecular weight and tacticity. It is, however, not clear what the effect of the magnitude of the molecular weight (differences in molecular weight of individual components) and a variation in tacticity are. For better understanding of the recrystallization process, modulated DSC (MDSC) was used to analyze the (PP6/PP7) blend as shown in Fig. 4. The MDSC reversible (rev), nonreversible (nonrev) and total heat flow traces of the (PP6/PP7) blend can be seen in Fig. 4.

MDSC, in which a small sinusoidal oscillation (modulation) is superimposed on the conventional linear heating programme, is a useful thermal analysis technique to separate the total heat flow (such as that acquired from conventional DSC) into the heat capacity related (reversible) component and heat flow and kinetic (nonreversible) components [23]. The reversible heat flow is calculated by multiplication of the heat capacity with the negative heating rate. The kinetic component or nonreversible heat flow is the arithmetic difference between the total heat flow and the reversible heat flow. Thus, exothermic signals are detected only in the nonreversible data, but endothermic melting behavior can contribute to both reversible and nonreversible signals [24]. Hence, MDSC can separate exotherms (including crystallization and recrystallization) from glass transitions, reversible melting, or other heat capacity related events. The MDSC revealed the remarkable contribution of the technique in characterizing the broad recrystallization exotherms which showed how recrystallization controls the results. Because of offsetting exotherm and endothermic processes, the exotherm is barely detected by conventional DSC at different heating rates, as was reported previously by Lee and Porter [25], and many others [23, 24, 26]. However, using MDSC, as seen in Fig. 4, in the nonreversible heat flow curve, there is an exothermic peak followed by an endothermic peak. Since the nonreversible component is kinetic in nature and can be attributed to nonreversible melting and crystallization on heating, the existence of the processes of recrystallization and melting on heating was confirmed in the (PP6/PP7) blend. The reversible heat flow curve shows that double reverse melting peaks exist. The appearance of double melting peaks is due to the recrystallization processes. The endothermic peak in the nonreversible heat flow curve corresponds to the highest temperature endothermic peak

in the curve for the reversible heat flow i.e. the two peaks in the reversible heat flow data correspond to the nonreversible and reversible components of the melting of recrystallized materials, respectively.

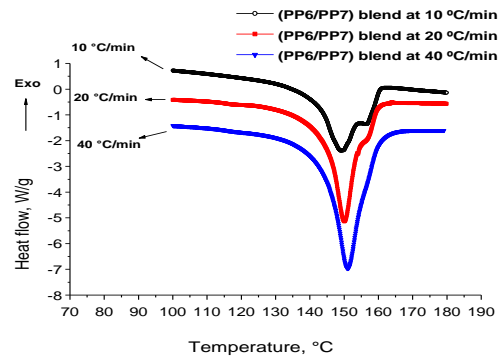


Fig. 3. DSC thermograms of the (PP6/PP7) blend at different heating rates

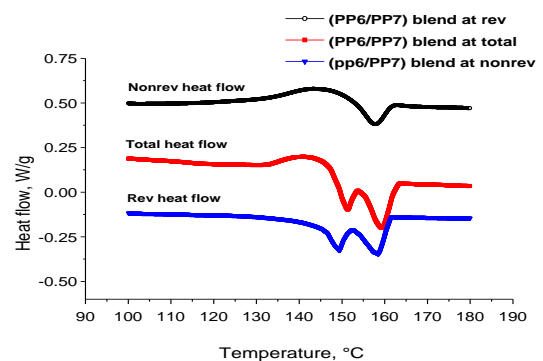


Fig. 4. MDSC heat flow curves of the (PP6/PP7) blend

Thus, the remaining reversible melting peak indicates the melting peak of the original crystals in the blend. This means that the PP6 and PP7 polypropylene polymers show a miscible blend.

3.2. Morphological properties

3.2.1. Optical microscopy analysis

Fig. 5 shows the OM micrographs of an isotactic polypropylene blend of the two isotactic polypropylene samples PP4 and PP5. As can be seen from Fig. 5, the (PP4/PP5) blend (Fig. 5 c) exhibited a large number of spherulitic crystals of isotactic polypropylenes crystallized from the melt [27]. The only slight difference between the polypropylene homopolymers and the blend are the size of the crystals and the manifestation of birefringence. These results indicate that the two isotactic polypropylene polymers are miscible.

Fig. 6 shows the OM micrographs of isotactic polypropylene PP2, syndiotactic polypropylene (SPP) and the isotactic/syndiotactic polypropylene blend, (PP2/SPP), respectively.

The syndiotactic polypropylene appeared as needle-like entities (Fig. 6 b), whereas spherulites were observed in the case of isotactic polypropylene (Fig. 6 a). The presence of syndiotactic polypropylene appeared to influence the growth and size of isotactic polypropylene spherulites in the (PP2/SPP) blend, resulting in a grainy crystal structure (Fig. 6 c). As observed in Fig. 6 c, for the (PP2/SPP) blend, isotactic polypropylene spherulites can hardly be seen, indicating a decrease in the crystal size.

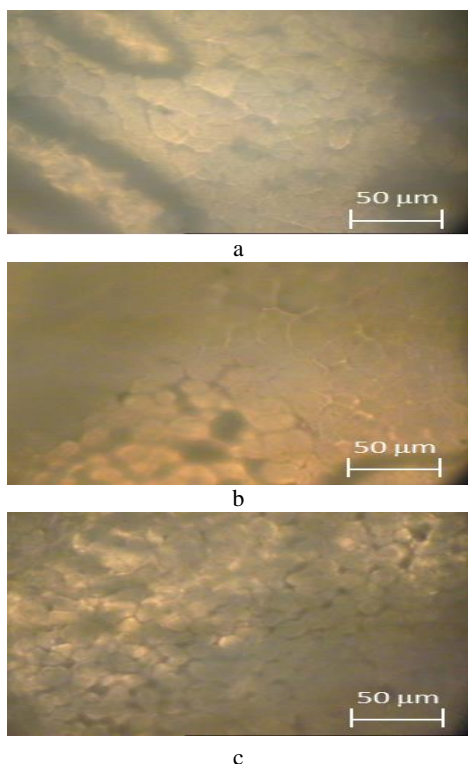


Fig. 5. Optical micrographs of isotactic polypropylene samples and their blend: a–PP5; b–PP4; c–(PP4/PP5) blend (500x magnification)

The small and imperfect crystallites formed in the (PP2/SPP) blend are beneficial to promote the elasticity of isotactic/syndiotactic polypropylene blends [15, 16]. Similar results were reported in a number of articles [11, 15, 16, 28].

3.2.2. Scanning electron microscopy analysis

Fig. 7 c shows the SEM micrograph of an isotactic polypropylene blend of the two isotactic polypropylene samples PP5 and PP4 (Fig. 7 a and b). All these isotactic polypropylenes revealed well-defined and large spherulitic morphology. In contrast to the OM results, clear differences were distinguished between the isotactic polypropylenes shown in Fig. 7. These differences exist in the variety of spherulite sizes and spherulite types classified by their appearance, including the sign and nature of birefringence and crystal lattice. The average diameter of PP5 spherulites was about 5–15 μm (Fig. 7 a), whereas smaller dominant α spherulites (about 5–10 μm) were observed for PP4 and the (PP4/PP5) blend (Fig. 7 b and c respectively). The sign and nature of birefringence and crystal lattice of the α -spherulites of the (PP4/PP5) blend could also be clearly observed to be similar to those of the polypropylene sample with higher molecular weight as illustrated in Fig. 7 .

Also, the (PP4/PP5) blend had the same type of α -modification spherulite structure of isotactic polypropylenes, which indicates that the two isotactic polypropylene samples PP4 and PP5 are miscible polymers [29, 30]. Fig. 8 c shows the SEM micrograph of the blend (PP2/SPP) of isotactic polypropylene sample PP2 (Fig. 8 a) and syndiotactic polypropylene sample SPP (Fig. 8 c).

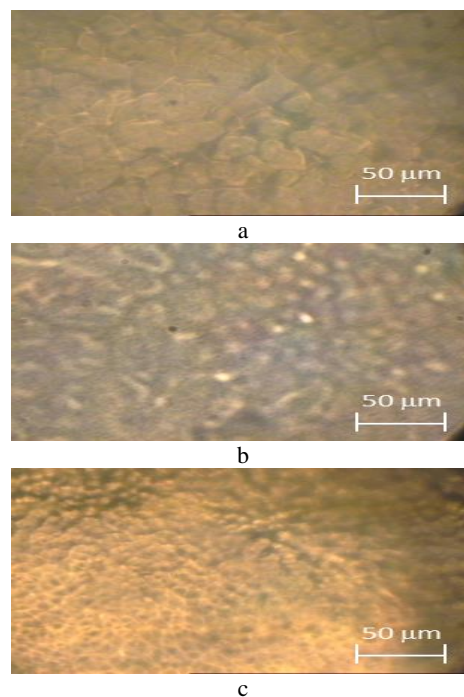


Fig. 6. Optical micrographs of: a–isotactic polypropylene PP2; b–syndiotactic polypropylene SPP; c–(PP2/SPP) blend (magnification: 5 x 10²)

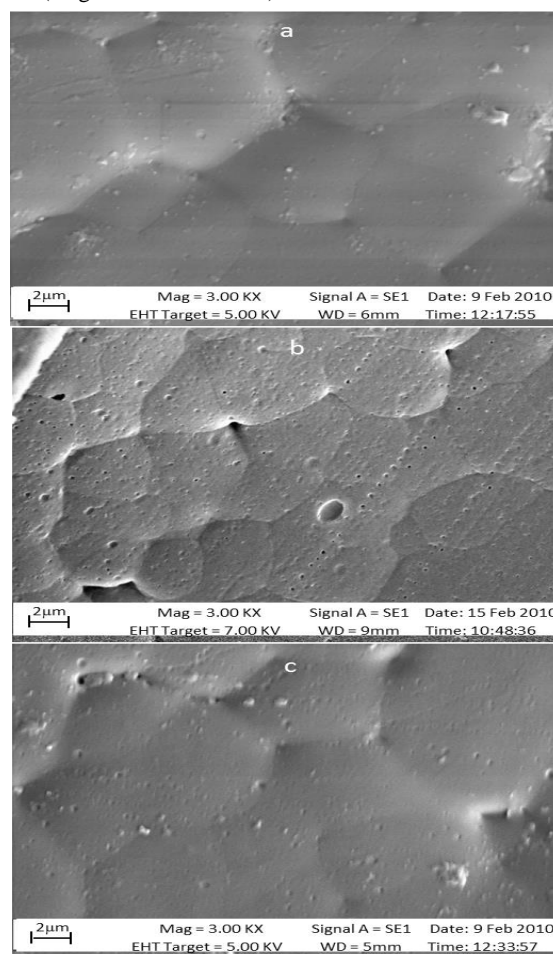


Fig. 7. SEM micrographs of isotactic polypropylene polymers and their blend: a–PP5; b–PP4; c–(PP4/PP5) blend (3000x magnification)

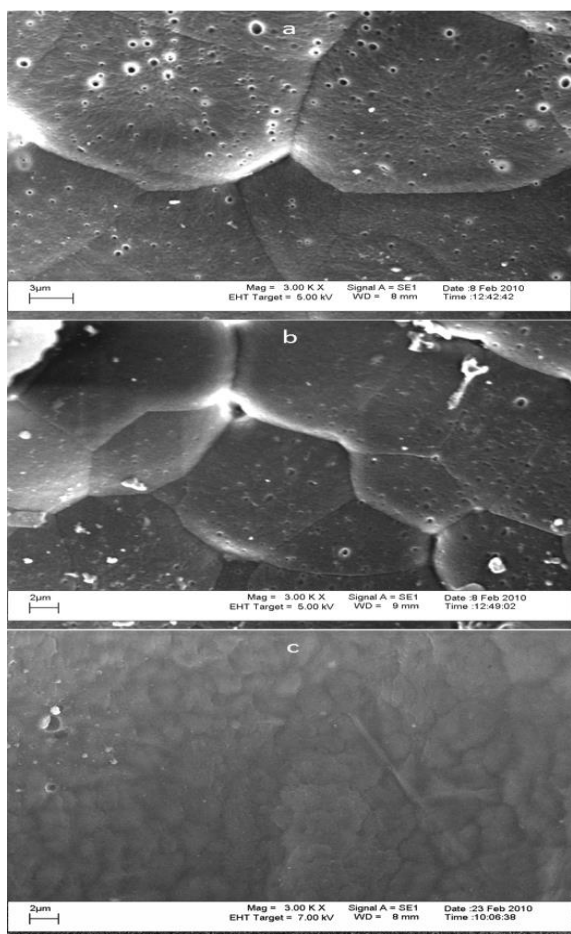


Fig. 8. SEM micrographs of: a–PP2; b–SPP; c–(PP2/SPP) blend (3000x magnification)

Similar to what was observed with the OM results (Fig. 6 c); SEM micrographs of the (PP2/SPP) blend displayed a grainy crystal structure. This indicates that the presence of syndiotactic polypropylene influences the growth and the size of isotactic polypropylene spherulites, which leads to less perfect spherulites. Similar results were obtained by Thomman et al. [31] and Bourbigot et al. [32]. They found that isotactic and syndiotactic polypropylene blends are phase separated and that crystallization of isotactic and syndiotactic polypropylenes in the blend occurs separately. They also found that crystallization of isotactic and syndiotactic polypropylene blends is dependent on the crystallization nature of the individual components. The SEM micrograph (Fig. 8 a) also displayed small dimples on the etched surface of PP2 sample, which sometimes grew to craters and holes. This was the result of the extractions of the rubbery materials by the etchant solution [33–36].

3.3. Mechanical properties

In order to correlate the structure of the polypropylene blends with the mechanical properties, the samples were analyzed using microhardness and DMA.

3.3.1. Microhardness

According to literature [37–42], all the parameters that lead to an increase of crystallinity and crystallite sizes (lamellar thickness) will also lead to higher MH values. Hence, the higher the isotacticity, the greater the MH

values obtained.

The results of the MH of different polypropylene blends (50/50 wt.%) are shown in Table 2. According to Flores et al. [40], MH of a polymer blend can be described in terms of an additive system of two independent components, as illustrated in the Eq. 1 below.

$$MH_b = MH_1 \phi + MH_2 (1 - \phi), \quad (1)$$

where MH_b is the hardness of the blend, MH_1 and MH_2 are the hardness values of the single components, and ϕ is the weight fraction of component 1. However, deviations from this equation may occur, depending on the variation in crystallinity of each phase in the blend. As can be seen in Table 2, the blends of the two different isotactic polypropylenes (PP9/PP10) and (PP1/PP3), have MH values between the values of the two homopolymers, which depend on the type and degree of the crystallinity of the blends.

It is reasonable that the higher isotacticity content in the blend allows easier recrystallization upon the application of an external force to the sample, thus improving the hardness of the sample upon indentation. This correspondence to results obtained by De Rosa et al [43]. They found that MH values increase with increasing isotacticity of polypropylene polymers.

It is also noteworthy that the syndiotactic polypropylene sample (SPP in Table 2) has a low MH value, due to its low degree of crystallinity and different type of crystals. The presence of syndiotactic polypropylene in the (PP2/SPP) blend led to a decrease in the MH value of the isotactic polypropylene sample PP2 (Table 2). This was due to a reduction in the growth and the size of isotactic polypropylene spherulites, which lead to less spherulite perfection, as can be observed in the OM and SEM results. These results agreed with the results obtained by Misheva et al. [44]. They showed that MH values decrease with the syndiotactic content of the studied syndiotactic polypropylene samples.

Table 2. MH results of different polypropylene blends (50/50 wt.%)

Sample	Hardness, HV 0.01	<i>mnmn</i> , %	M_w , g/mol	MWD	X_c , %
PP9	7.5	93.0	184 759	6.1	50.0
PP10	6.2	93.0	65 498	8.2	48.0
(PP9/PP10) blend	6.6	–	–	–	51.0
PP1	7.4	94.0	252 956	5.4	50.0
PP3	6.1	86.0	215 397	5.9	43.0
(PP1/PP3) blend	6.3	–	–	–	44.0
PP2	7.7	96.0	271 974	5.6	52.0
SPP	4.2	93.0 ^a	174 000	2.3	16.0
(PP2/SPP) blend	4.8	–	–	–	36.2
^a Syndiotacticity (<i>rrrr</i> %)					

3.3.2. Dynamic mechanical analysis

Fig. 9 shows the storage modulus curves as a function of temperature for a 50/50 wt.% (PP1/PP3) blend of the two isotactic polypropylene samples PP1 and PP3. Fig. 10 shows the storage modulus curves as a function of temperature for a 50/50 wt.% (PP2/SPP) blend of isotactic and syndiotactic polypropylene samples. Over the full temperature range of the experiment, the storage modulus curve of the blend of the two isotactic polypropylenes was always between the storage modulus curves of the two isotactic homopolymers, which indicates that the two

isotactic polymers are miscible.

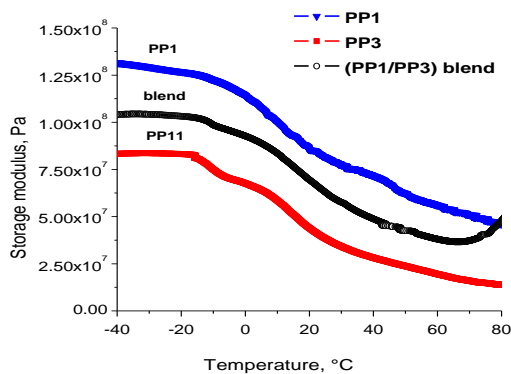


Fig. 9. Storage modulus values as a function of temperature for a 50/50 wt.% (PP1/PP3) blend of two different isotactic polypropylene samples

However, the storage modulus curve of the isotactic/syndiotactic polypropylene blend (PP2/SPP) in Fig. 10 displayed different behaviour.

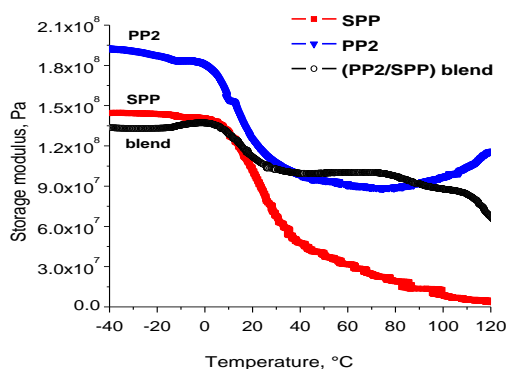


Fig. 10. Storage modulus values as a function of temperature for a 50/50 wt.% (PP2/SPP) blend of isotactic and syndiotactic polypropylene samples

Within the temperature range of -40 to 10 °C (below the T_g), the (PP2/SPP) blend showed a lower storage modulus value than both PP2 and SPP homopolymers. Above 10 °C, the storage modulus of the (PP2/SPP) blend increased above the storage modulus values of the syndiotactic polypropylene sample SPP. This could be due to the partial miscibility of the isotactic and syndiotactic polymers at temperatures higher than their glass temperatures. Our results are slightly different from the results obtained by Zhang et al. [45]. They found that within the temperature range from -25 to 0 °C, the storage modulus values of syndiotactic polypropylenes decreased rapidly, while the storage modulus values of isotactic/syndiotactic polypropylene blends changes are much less significant than syndiotactic polypropylene. They also found that within the whole temperature range of the experiment, the storage modulus values of the blends are always lower than isotactic polypropylene samples, except for isotactic/syndiotactic polypropylene (90/10) blend, in which the highest storage modulus values were obtained. They attributed the high storage modulus values for isotactic/syndiotactic polypropylene blend (90/10) to the miscibility of isotactic/syndiotactic polypropylene (90/10) blend.

Generally, and as shown above in the OM and SEM results, the addition of syndiotactic polypropylene markedly affects the isotactic polypropylene spherulites and creates defects in the isotactic polypropylene crystals. This results in a decrease in the crystallinity of the blends, leading to a decrease of storage modulus values for the isotactic/syndiotactic polypropylene blends.

4. CONCLUSIONS

The effect of isotacticity and molecular weight on the thermal, morphological and mechanical properties of different polypropylene blends was investigated. The major factors affecting the structure and properties of polypropylene blends are those that lead to an increase of crystallinity. DSC and MH results indicated that the thermal and mechanical properties of polypropylene blends are considerably affected, not only by the tacticity, but also by the molecular weight of the polypropylenes. Furthermore, DSC, OM, SEM, MH and DMA indicated that blends of two different isotactic polypropylene samples are good miscible polymers. Whereas blends of isotactic and syndiotactic polypropylene samples are immiscible polymers, which lead to a decrease in the MH and storage modulus values of the isotactic/syndiotactic polypropylene blends.

Acknowledgements

The authors would like to thank 1) the International Centre of Macromolecules and Materials Science (Libya) for financial support for Ismael Amer and 2) Mrs Sonja Brandt for the English editing.

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