The role of interfacial elasticity on the rheological behavior of polymer blends

Jorge M. Silva¹, Ana V. Machado¹, Paula Moldenaers² and João M. Maia¹,³,*

¹Department of Polymer Engineering, I3N-Institute of Nanostructures, Nanomodelling and Nanofabrication, University of Minho, 4800-058 Guimarães, Portugal
²Department of Chemical Engineering, Katholieke Universiteit Leuven, W. de Croylaan 46 - B 3001 Heverlee(Leuven), Belgium
³Department of Macromolecular Science and Engineering, Case Western Reserve University, Cleveland, OH 44106-7202; USA

(Received August 13, 2009)

Abstract

In this work, the influence of interfacial modification on the rheological behavior of polymer blends was investigated. First, commercial blends of polyamide-6 and ethylene-propylene copolymer, PA6/EPM, non-compatibilized and compatibilized with EPM grafted with maleic anhydride, with high viscosity and elasticity ratios were studied. The observation of the morphology frozen during extension tests seemed to indicate that the droplets of the highly compatibilized blends are slightly deformed unlike those of the non-compatibilized ones. Stress relaxation experiments, both in shear and extension, showed that the introduction of the compatibilizer leads to the appearance of a second very long relaxation mechanism, the question then being what is its cause. In order to better understand the relative importance of relaxation of the droplets and relaxation of the interfaces in this kind of compatibilized blends, model high viscosity ratio blends of optically transparent materials, in this case poly(methylmethacrylate), PMMA, polystyrene, PS, and oxazoline-modified polystyrene, PSOX were prepared. This allows Small Angle Light Scattering (SALS) to be used in dilute blends to complement the rheometrical characterization and thus evaluate the deformation of the droplets in transient shear flows. In these blends there is also an additional longer relaxation time present but no changes in the morphology can be readily observed. In addition, the blend with functionalized PS shows a droplet deformation in the vorticity direction, which is an indication of an increase in the elasticity of the interface. Thus, our findings seem to indicate that the main factor behind the increase in relaxation time stress relaxation at and in the interfaces and not droplet deformation and recovery. The role of the elasticity of the interface became quite clear when PP/EVOH blends, non-compatibilized and compatibilized with Na⁺ were tested. In this case the elasticity of the interface is negligible and it was observed that the compatibilization does not affect significantly the relaxation behavior after a step deformation.

Keywords: interfacial elasticity, polymer blends, compatibilization, stress relaxation.

1. Introduction

Blending polymers is a good way to obtain new materials at relatively low cost. However, most of polymers are immiscible, leading to the formation of polymer blends with bad properties for industrial purposes. This problem is usually overcome by the use of compatibilizers, which act on the interface between the polymers, increasing their interfacial adhesion.

There are different strategies to achieve compatibilization such as the addition of a premade grafted or block copolymer, the in-situ formation of a copolymer, the introduction of specific interactions between the polymers (such as Van der Waals interactions, hydrogen bonding, ion-dipole interaction or ion-ion interactions), the addition of ionomers, or the use of nanoparticles (Datta and Lohse, 1996a; Datta and Lohse, 1996b; Utracki, 1994, He et al., 2004; Koning et al., 1998; Vermant et al., 2008). The addition of a premade grafted or copolymer allows better control of the molecular architecture of the compatibilizer than in the case of in-situ formation. However, this last route has the advantage that the generation of the compatibilizer is performed in situ at the interface directly during blending.

Several studies (p.e., Van Puyvelde et al., 2003; Van Puyvelde et al., 2001; Van Hemelrijck et al., 2004) show that compatibilization increases the interfacial adhesion between the components of the blend, produces a finer morphology and delays the coalescence of the dispersed phase. As could be expected, these differences in the inter-
facial proprieties and morphology induce different rheological responses of the blends when subjected to flow. For example, when submitted to small amplitude oscillatory shear, immiscible binary blends show a higher elasticity in the low frequency range than that of the combined individual components. In fact, the relaxation of the shape of the dispersed phase when shear deformed (Graebling et al., 1993; Oosterlinck et al., 2003) causes the appearance of a secondary plateau in storage modulus at low frequencies. When a compatibilizer is added to the blend an additional relaxation time is observed. This relaxation time has been attributed to the relaxation of Marangoni stresses tangential to the interface between the dispersed phase and the matrix (Riemann et al., 1997; Van Hemelrijck et al., 2004). They are caused by a gradient of interfacial tension, induced by a gradient of compatibilizer concentration at the interface (Van Hemelrijck et al., 2004; Van Puyvelde et al., 2001).

This additional relaxation time in compatibilized blends is predicted by the Palierne model if an interfacial shear modulus is introduced (Jacobs et al., 1999) Several authors (Yee et al., 2007; Huo et al., 2007; Shi et al., 2002; Ashana and Jayaraman, 1999) used this generalized version of the Palierne model and obtained good agreement with the experimental data in compatibilized blends. However, Sailer and Handge (2007), studying blends of PA 6/SAN compatibilized with styrene-acrylonitrile-maleic anhydride terpolymer (SAN-MA) concluded that the generalized Palierne model could not be fitted to the experimental data for reasonable values of interfacial tension and interfacial shear modulus.

There are also in literature studies concerning with the behavior of immiscible polymer blends when subjected to extensional flows, but in much less quantity than for shear flows. The elongation and subsequent recovery of poly (methyl methacrylate)-polystyrene (PMMA/PS) blends, as well as the evolution of the morphology, were studied by Gramespacher and Meissner (1997) and, more recently, by Mechbal and Bossuina (2004) and Handge and Potschke (2004). In terms of recovery after melt elongation, the results suggest that, as in shear flows, there is a fast molecular recovery related with each component and a slow one associated with interfacial tension. In terms of elongational flow, Mechbal and Bossuina (2004) observed that the behavior of a PMMA/PS (95/5) blend is mainly dominated by the matrix. Oosterlinck et al. (2005), while also studying PMMA/PS blends subjected to uniaxial elongational flows, verified that the extra stress due to droplet deformation can, in principle, be deduced from extensional rheological measurements.

Very few studies reported the behavior of compatibilized blends in extensional flows. Mechbal and Bossuina (2007) studied the effect of the diblock copolymer addition on the rheology and morphology development during uniaxial elongation and during relaxation after cessation of flow on a PMMA/PS blend with viscosity ratio lower than 1. They observed that when the concentration of the copolymer is above a critical concentration, the interface becomes saturated, the droplets are less deformed and the relaxation is slower. They postulated that this behavior is due to local entanglements, which resist deformation. Moreover, it was concluded that if the molecular weight of copolymer is smaller than the critical molecular weight of entanglement of both PS and PMMA then the copolymer does not affect the stress relaxation behavior. Recently, Yee et al. (2009) performed step shear strain experiments and found that the sheared droplet is less deformed upon addition of random copolymers and that the relaxation process is delayed.

Also, rheological transient shear experiments have shown that the compatibilization has an important effect on rheological properties (Iza et al., 2001; Macaubas et al., 2005; Silva et al., 2007), which suggest a large contribution of the modified interface to the overall behavior.

However, many questions remain unanswered. In particular, how do the interfaces modified by the compatibilizer relax and what are the consequences in the rheological behavior? Moreover, the studies concerning extensional rheology of polymer blends specially compatibilized polymer blends are extremely rare. In this work linear and non-linear (relaxation both in shear and extension) experiments will be performed on high-viscosity blends, the rationale for this being that we are interested in maximizing the relative effect of the interface by comparison with the droplet deformation. Additionally, in order to investigate the characteristics of the interfaces rheo-optical measurements will also be performed.

2. Experimental

2.1. Materials and compounding

In this work three sets of blends were studied. First, several blends of a commercial polyamide-6 (PA-6 Akylon K123), an ethene-propene rubber (EPM Keltan 740) and an ethene-propene rubber modified with maleic anhydride (EPM-g-MA ExxelorVA 1801, containing 0.49 wt% of MA, as determined by FT-IR) were prepared in a twin screw extruder, under the same process conditions (the screws rotating at 200 rpm, with a flow rate of 6 kg/h and set temperatures of 220–230°C in the barrel and 220°C at the die). The PA-6 content was kept constant in all blends, but the amount of modified rubber was varied in order to have different amounts of maleic anhydride in each blend and thus various amounts of compatibilizer at the interface. In all these blends both the viscosity and elasticity ratios are very high, i.e., more than 10 and in some cases 100.

The second group of blends was chosen in such a way that the viscosity ratios are still higher than 1, but the materials are all optically transparent, so that optical morpho-
logical analysis can be performed. These blends were made of PMMA (Altuglas VSE UV7, MFI 27 g/10 min at 230°C with 3.8 Kg), PS (Solarene G116, MFI 2.3 g/10 min at 200°C with 5 Kg) and oxazoline functionalized PS, PSOX (Epolcor RPS-1005, 6–10 g/10 min at 200°C with 5 Kg) which was provided by Nippon Shokubai. In the PSOX the weight of oxazoline groups corresponds to 1.9% of the total weight. A series of blends of PP/PS/PSOX were prepared. Again, the concentration of the PMMA matrix was kept constant (80 w/w%) while that of PS and PSOX were varied from a maximum of PS and no PSOX (80/20/0 PMMA/PS/PSOX) to the opposite situation, i.e., 20 w/w% of PSOX and no PS (80/0/20 PMMA/PS/PSOX). Moreover, two diluted blends (99/1/0 PMMA/PS/PSOX and 99/0/1 PMMA/PS/PSOX) were also prepared. A Haake batch mixer at a set temperature of 210°C, 2160 g), and a density of 1.19 g/cm³. The Na⁺ ionomer (Surlyn resin 8528, from Du Pont, Wilmington, DE, USA) is a random ethylene/methacrylic acid copolymer partially neutralized with sodium, with a MFI of 1.10 g/10 min (190°C, 5000 g) and a density of 0.93 g/cm³.

2.2. Rheometry

The rheological measurements in shear were performed with an ARES rheometer (TA instruments), using a parallel plate geometry (diameter=25 mm) with a 1.0 mm gap. All samples were vacuum dried (80°C during 12 h) before each rheological experiment.

PA6/EPM/EPM-g-MA blends were tested in a nitrogen atmosphere, preliminary time sweep measurements at constant frequency having been performed in order to ensure that neither polymerization nor degradation occurred during the frequency sweep tests. In these blends, oscillatory tests were performed at 3 different temperatures (240, 260, 280°C). In PMMA/PS/PSOX and PP/EVOH/Na⁺ blends the test in shear were performed at 230 and 220°C respectively. The stress relaxation experiments in shear were performed again using a parallel-plate geometry (diameter=25 mm) with a 1.0 mm gap; for PA6/EPM/EPM-g-MA and PMMA/PS/PSOX a shear rate of 0.1 s⁻¹ during 250 s was applied and the evolution of the shear stress upon cessation of flow was measured. For PP/EVOH/Na⁺ blends, a shear rate of 0.1 s⁻¹ during 25 s was used. In the PA6/EPM/EPM-g-MA blends stress relaxation in shear experiments were performed at 240°C.

The extensional rheological measurements were performed on the MRR (Modified Rotational Rheometer) developed by Maia et al. (1999). For relaxation extensional experiments, samples with rectangular cross-section (about 3 x 2 mm), prepared by compression molding, were used in order to increase the signal (force) measured by the rheometer. Upon loading onto the rheometer, residual stresses were first allowed to relax; once the measured torque decayed to zero any existing slack was removed and once again the stresses were allowed to relax. The effective length of each sample was 40 mm and the diameter varied between 2 and 3 mm, thus yielding an aspect ratio, L/D, ranging between approximately 13 and 20. This has been shown (Barroso et al., 2002) to be high enough for shear-related end-effects to be negligible. During all experiments the samples were immersed in silicone oil at the test temperature for the dual purpose of temperature control and sagging prevention. The temperature of silicone oil was 240°C for PA-6/EPM/EPM-g-MA blends and 205°C for PMMA/PS/PSOX blends (the highest temperature at which the sample yielded a strong enough signal to be measured). The particular details on the experimental technique to measure the stress relaxation after an extensional step strain are given in Barroso and Maia (2002) and Barroso et al. (2003).

2.3. Morphology

In order to study the morphology of PA6/EPM/EPM-g-MA blends undergoing extensional deformations, the oil bath was rapidly removed during an experiment and the deformed sample was quenched in liquid nitrogen (the whole process takes only 2 to 3 seconds) while the deformation is still being imposed. This means that no significant morphological changes, such as droplet relaxation and/or coalescence, should occur during the quenching process. Once solidified, the samples were fractured longitudinally in liquid nitrogen, etched with boiling xylene to remove the rubber from the surface and gold plated; their morphology was studied using a Jeol JSM 6310F Scanning Electron Microscope.

2.4. Interfacial tension measurements

The interfacial tension between PMMA and PS and PSOX was measured by the pendant drop method using a OCA device from DataPhysics. The material with lower density, PS or PSOX, was melted in a transparent cell. The material with higher density, PMMA, was melted in a needle and then injected in PS or PSOX to form a drop. The temperature of the system was kept constant, 210°C. The evolution of drop shape was recorded with a camera. The contours of the droplets were fitted to the Laplace-Young equation using the SCA software.
2.5. Small Angle Light Scattering (SALS)

Small angle light scattering measurements (SALS) were performed to study the deformation of the droplets and the interface in PMMA/PS/PSOX diluted blends. Light emerging from a He-Ne laser (~633 nm) is sent through the sample that is contained within a Linkam shear cell (CSS 450). The anisotropy of the SALS patterns can be quantified calculating a second moment tensor from the measured light intensity on the 2D CCD array. Then, the anisotropy, ε, is given by the difference between the eigenvalues of this tensor (Borschig et al., 2000):

\[ \varepsilon(\gamma, t) = \left( \frac{I_{\gamma}(q, \gamma, \beta, \eta)}{I_{\gamma}(q, \gamma, \beta, \eta)} - 1 \right)^2 \]

This calculation was done using in-house developed SalsSoftware from K. U. Leuven. To avoid multiple scattering only the diluted blends (99/1/0 and 90/0/1) were used in the SALS experiments. The experiments were performed at 230°C.

3. Results

Fig. 1 shows the storage modulus of the PA6/EPM/EPM-g-MA blends and their components. At high frequencies the storage modulus of the non-compatibilized blend (80/20/0) is lower than the moduli of both components. This negative deviation behavior, which probably originates in slip at the interfaces (Utracki, 1983; Van Puyvelde et al., 2003) due to poor or insufficient compatibilization between the matrix and the dispersed phase, is suppressed by the addition of compatibilizer. This behavior is not predicted by the existing theoretical models since most do not take into account slip between the phases. At low frequencies, the characteristic increase in moduli of the blends relatively to the individual components is observed.

However, the most pronounced effects of compatibilization are observed in stress relaxation experiments. After a deformation in shear the blends relax in two consecutive steps (Fig. 2). The first (faster) step is related with the relaxation of the PA6 matrix, and the second (slower) step is probably due to relaxation of EPM and/or interfaces. For the compatibilized blend this second relaxation time is much longer than for the non-compatibilized one.

As in the shear relaxation experiments, in the extensional relaxation (after a step strain) experiments, the compatibilized blend exhibits higher relaxation times (Fig. 3). Once more, the fast relaxation time can be attributed to the PA6 matrix and the slow one to the interface and/or rubber dispersed phase. These results suggest that the presence of slip at the interface inhibits the deformation of dispersed phase droplets and that this is suppressed by the addition of the compatibilizer. To confirm this assumption, the morphology of stretched samples was observed by SEM.

The results (Silva et al., 2007) of the morphological analysis showed that the morphologies of the non-compatibilized blend both before extension and quenched during extension are essentially the same both in terms of type of morphology (droplet) and in terms of particle size. Thus, there was no (or only negligible) deformation of the rubber phase upon extension, due to interfacial slip. In the compatibilized blend the average droplet size is much smaller, as would be expected and the morphologies before and after extension are different. In the former case the expected spherical droplet morphology is seen and in the latter the droplets are slightly elongated. This is an indication that the compatibilizer was present in a high enough content to make the drag force on the droplets overcome the resistance to flow/deformation of the rubber phase (note that the viscosity ratio is very high in these materials).

To better understand the influence of compatibilization on the droplet and interfacial deformation another type of blends was studied: PMMA/PS/PSOX. As mentioned...
The role of interfacial elasticity on the rheological behavior of polymer blends

Before, the focus remains in the blends with viscosity and elasticity ratios higher than 1 but that are optically transparent so that rheo-optical measurements can be performed in addition to rheometrical ones, Silva et al. (2009).

The elastic moduli of these blends and their pure components are shown in Fig. 4. The non-compatibilized PMMA/PS blend shows the typical shoulder in $G'$ and contrarily to previous PA6/EPM non-compatibilized blends their dynamic moduli can be fitted to the Palierne model. The addition of modified polystyrene causes an increase of dynamic moduli at low frequencies. For high concentrations of PSOX the elastic modulus shows a gel-like behavior (a plateau) at low frequencies. Moreover, the observed plateau (also previously observed by other authors in compatibilized blends, e.g., Yee et al., 2007; Sailer and Handge, 2007; Fahrlander et al., 2001), suggests that the extra interactions at the interface play a crucial role in the rheological behavior, inclusively being more important than the average size and size distribution of the dispersed phase. Thus, it seems that the amount of oxazoline has an important role in the elasticity of the interfaces.

This behavior cannot be explained by the relaxation of droplets of the dispersed phase only. For example, if one tries to fit any form of the Palierne model to the data of the blends with higher concentrations of PSOX, the obtained values of the interfacial tension are totally unrealistic. Although no new chemical bonds were detected in FTIR tests, interfacial tension results indicate that there are additional physical interactions in blends containing PSOX.

Fig. 5 shows the evolution of interfacial tension for both PMMA/PS and PMMA/PSOX measured through drop shape. In both cases the shape of the drop becomes nearly constant after some time. A slightly lower value of interfacial tension is observed for PMMA/PSOX (3.0 mN/m) than for PMMA/PS (3.4 mN/m).

A possible physical cause for this compatibilization effect is the creation of hydrogen bonds and reinforced Van der Waals interactions between PMMA and PSOX.

As for the previous set of blends (PA6/EPM/EPM-g-MA), stress relaxation experiments were performed on PMMA/PS/PSOX blends, Figs. 6 and 7, and in both cases the introduction of PSOX causes a big increase in the relaxation time of the blends.

In PA6/EPM/EPM-g-MA blends the suppression of slip between the phases by the introduction of compatibilizer seems to play a role in the increase of the relaxation time (although its importance cannot be judged a priori). In these blends this does not seem to be the case and in order to further study the origins of the effect, Small Angle Light Scattering, SALS, experiments were performed.

As mentioned before, in order to avoid the problems associated with multiple scattering, dilute samples (1 w% of PS or PSOX in PMMA) were prepared for SALS inves-
In these experiments samples being sheared at 2.5 s\(^{-1}\) were, after 800 seconds, submitted to a shear rate step to 70 s\(^{-1}\), at which they are maintained for 250 s. After this time, the shear is suddenly removed and the sample is allowed to relax quiescently in time. The Hencky strains, in percentage, applied to each sample are as shown.

For the 99/1/0 blend the SALS pattern deforms highly in the vorticity direction, thus indicating that the dispersed phase is being deformed in the flow direction (Fig. 8). Moreover, the anisotropy shows an overshoot characteristic of orientation and/or breakup of the droplets. When flow is stopped the SALS pattern takes about 5 seconds to recover the isotropic shape, i.e., for the stresses to relax completely, which is within the same timescale observed in stress relaxation experiments in shear (Fig. 7).

Fig. 9 depicts the results for the 99/0/1 blend and it too shows the existence of an overshoot in the anisotropy, but much smaller than for the 99/1/0 blend. Initially the droplets deform in the flow direction as was observed for PMMA/PS blend. However, at long times the anisotropy pattern appears slightly deformed in the vorticity direction, a trait that is present even upon the cessation of flow, which is an indication that the dispersed phase is slightly deformed in the vorticity direction. Deformation of the dispersed phase in the vorticity direction at relatively high shear rates is not common but was reported by several authors (Hobbie and Migler, 1999; Lin et al., 2005; Mighri and Huneault, 2006; Migler, 2000) in blends whose droplets are more elastic than the matrix, which is the present case. Although this phenomenon depends critically on the difference in the elasticity of the components, this alone cannot explain the observed behavior because the elasticity ratio between the PSOX and PMMA is relatively low and is even lower than that between PS and PMMA (see Fig. 4). Thus, the results

Fig. 6. Normalized transient extensional stress for concentrated blends of PMMA/PS/PSOX and their components after a step extension, at 205°C. The difference between time and time that corresponding to maximum stress is represented in x-axis. The stress is normalized by its maximum. The Hencky strains, in percentage, applied to each sample are as shown.

Fig. 7. Normalized transient stress for concentrated blends of PMMA/PS/PSOX and their components after cessation of a steady shear flow of 0.1 s\(^{-1}\) for 250 s, at 230°C.

Fig. 8. Anisotropy as a function of time for the 99/1/0 blend. A step-up in shear from 2.5 s\(^{-1}\) to 70 s\(^{-1}\) is performed and the flow is stopped 250 s later. Representative SALS patterns are shown for each stage.

Fig. 9. Anisotropy as a function of time for the 99/0/1 blend. A step-up in shear from 2.5 s\(^{-1}\) to 70 s\(^{-1}\) is performed and the flow is stopped 250 s later. Representative SALS patterns are shown for each stage.
of Fig. 9 (deformation on the vorticity direction) must be attributed to another factor in this case most likely an increase of elasticity in the interfaces caused by introduction of oxazoline groups (see Fig. 4). Even after the cessation of flow, the dispersed phase remains slightly elongated in the vorticity direction for a long time.

In conclusion, whereas for PA6/EPM/EPM-g-MA blends, the suppression of interfacial slip by the compatibilizer may (or may not) have a sizeable contribution for the observed increase in relaxation time, the present results for the PMMA/PS/PSOX blends indicate that the increase of the elasticity of interface should have at least a similarly (if not more) important role.

If this is true, then blends compatibilized in such a way that the interface is weakly elastic or inelastic should show little or no signs of the second slow relaxation mechanisms. One type of blends that falls in this definition is that of blends of PP and EVOH compatibilized through the addition of a Na⁺ ionomer. In previous works (Abad et al., 2004; Ares et al., 2009) was observed that from the point of view of the barrier properties, mechanical properties and morphology, the addition of low amounts of Na⁺ ionomer was an effective compatibilizer to the PP/EVOH blends. In these blends, however, the strength of ionic bonds decreases with increasing temperature and thus the interfacial interactions are expected to be weaker and give rise to much less elastic interfaces than in previous cases.

Fig. 10 shows the stress relaxation after cessation of shear flow for a non-compatibilized and a compatibilized blend and it is quite clear that within experimental error there is no increase in the relaxation time. In fact, for the compatibilized blend the relaxation kinetics seems to be slightly quicker than that of the PP matrix, although the differences are within the experimental error. As to the non-compatibilized blend, there is a slight delay of the relaxation but there is also no sign of the second relaxation mechanism. Thus, even though the experimental error is higher for these blends than for the previous ones, the results seem to indicate that in these blends the second relaxation mechanism is absent, which supports the findings and statements above regarding the importance of the elasticity of the interface.

4. Conclusions

In this work the role of compatibilization on the dynamics of interfaces, particularly in blends with viscosity ratios higher than one was investigated, the motivation being that the existing analytical models are not able to correctly predict the effect of compatibilization on rheological behavior of blends, particularly when viscoelastic components and viscosity ratios higher than one are involved.

In both PA6/EPM/EPM-g-MA and PMMA/PS/PSOX blends major effects of compatibilization in stress relaxation after cessation of flow, both in shear and extension were found. In these blends the introduction of compatibilizer causes a large increase in relaxation times and the appearance of an additional very slow relaxation mechanism.

In PA6/EPM blends with the morphology frozen upon an elongational deformation it was observed that the droplets of compatibilized blends were slightly elongated while in the non-compatibilized blend they were approximately spherical. This deformation of the droplets, which is due to a better adhesion between the phases, could, at least partially, explain the increase in relaxation time. However, the use of SALs in the transparent PMMA/PS/PSOX blends during the cessation of shear flow showed that the addition of high enough concentrations of oxazoline caused droplet deformation in the vorticity direction at high shear rates, although the morphology remained largely unaffected, which was taken as an indication of a strong increase in interfacial elasticity. Thus, the increase in relaxation time of PA6/EPM by introduction of compatibilizer should be explained not only by a higher deformation of the droplets but also, possibly mainly, by the additional physical interactions across the interface that increase its elasticity and slow down the relaxation.

This type of behavior is not universal and depends strongly on the type of compatibilization and the type of interactions that occurs at the interface. The first of the type of blends above was compatibilized through the addition of a reactive polymer while in the second one the introduction of the oxazoline groups led to formation of additional physical interactions; in both cases highly elastic interfaces are present and a similar rheological behavior was found. However, if different types of compatibilization are used, the nature of the interactions at the interface changes and
so does the rheological behavior. This was shown for blends of PP/EVOH compatibilized with a Na⁺ ionomer. Although, the effect of compatibilization through the presence of the ionomer is effective from the point of view of barrier properties, mechanical properties and morphology, the temperature dependence of the strength of the ionic bonds leads to an inelastic and relatively weak interface and thus does not cause an increase of relaxation time after deformation.

References


Borschig, C., B. Fries, W. Gronski, C. Weis and C. Friedrich, 2000, Shear-induced coalescence in polymer blends - simulations and rheo small angle light scattering, Polymer 41, 3029.

Datta, S. and D. Lohse, Polymeric compatibilizers (Hanser, Munich, 1996a).

Datta, S. and D. Lohse, Polymeric compatibilizers, uses and benefits in polymer blends (Hanser, Munich, 1996b).


Mechbal, N. and M. Bousmina, 2007, Effect of copolymer addition on drop deformation during uniaxial elongation and during relaxation after cessation of flow, Macromolecules 40, 967.


The role of interfacial elasticity on the rheological behavior of polymer blends