

RHEOLOGY OF POLYPROPYLENE/LIQUID CRYSTALLINE POLYMER BLENDS: EFFECT OF COMPATIBILIZER AND SILICA

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ABSTRACT:

The effect of classical compatibilizers and silica fillers, which are a new potential type of compatibilizers, on the rheological properties of PP/LCP blends was investigated. The frequency sweep, shear stress growth and stress relaxation upon cessation of steady shear were performed to probe the effect of the interfacial modification and the role of silica, on the rheological behaviour of the blend. It was found that SEBS-g-MA improves the interfacial interaction more than SEBS due to the possible chemical bonding between maleic anhydride groups and LCP chains. The results showed while the hydrophilic silica fills both matrix and the LCP dispersed phases, the hydrophobic silica has some compatibilizing effect on PP/LCP blend samples.

ZUSAMMENFASSUNG:

Diese Studie befasst sich mit dem Einfluss von klassischen Kompatibilisatoren und Silika-Füllstoffen, die einen neuen potentiellen Typ von Kompatibilisatoren darstellen, auf die rheologischen Eigenschaften eines PP/LCP-Blends. Frequenz-Sweeps, Spannversuche in Scherung und Spannungsrelaxationsexperimente nach Scherung wurden durchgeführt, um den Einfluss der Grenzflächenmodifikation und die Rolle von Silika auf die rheologischen Eigenschaften des Blends zu untersuchen. Die Untersuchungen zeigten, dass SEBS-g-MA die Grenzflächenanbindung stärker als SEBS verbessert, möglicherweise aufgrund der chemischen Bindung zwischen den Maleinsäureanhydridgruppen und den LCP-Ketten. Während das hydrophile Silika sowohl die Matrix als auch die disperse Phasen der LCP-Komponente füllt, besitzt das hydrophobe Silika eine kompatibilisierende Wirkung auf das PP/LCP-Blend.

RÉSUMÉ:

L'effet d'additifs classiques et de charges de silice, qui représentent potentiellement un nouveau type d'additifs pour rendre compatibles des mélanges de polymères, sur les propriétés rhéologiques de mélanges PP/LCP a été étudié. Des balayages en fréquence, des montées en contrainte de cisaillement et des relaxations de contraintes après cessation de cisaillement en régime établi ont été effectués afin d'explorer l'effet de la modification de l'interface et le rôle de la silice sur le comportement rhéologique du mélange. On a trouvé que le SEBS-g-MA améliore l'interaction à l'interface encore mieux que le SEBS. Ceci est dû à de possibles liaisons chimiques entre les groupes d'anhydride maléique et les chaînes de LCP. Les résultats montrent que la silice hydrophobe a un effet de liant sur les échantillons de mélanges PP/LCP, tandis que la silice hydrophile remplit à la fois la matrice et la phase dispersée de LCP.

KEY WORDS: polymer blends, compatibilization, liquid crystalline polymer, nano-silica

1 INTRODUCTION

Blends containing small amount of liquid crystalline polymers (LCP) in a flexible matrix are of industrial and academic interests because the LCP can lead to easier processing and enhanced mechanical properties [1, 2, 3]. Addition of compatibilizer has been found to improve the dispersion of the LCP phase and in some cases enhance the final mechanical properties of the blend systems. Better dispersion of LCP in the matrix through incorporation of a compatibilizer was

expected to be due the reduction of interfacial tension. Datta and Baird [4] and O'Donnel and Baird [5] used a maleic anhydride grafted polypropylene as a compatibilizer for polypropylene/LCP blends and found an improvement in the modulus of up to 30 %. Bualek-Limcharoen et al. [6] observed a significant improvement in Young's modulus and impact strength of in-situ composites comprising LCP and PP using a tri-block copolymer of styrene (ethylene-butylene) styrene (SEBS), as a compatibilizer. Wannou et al. [7] studied the performance

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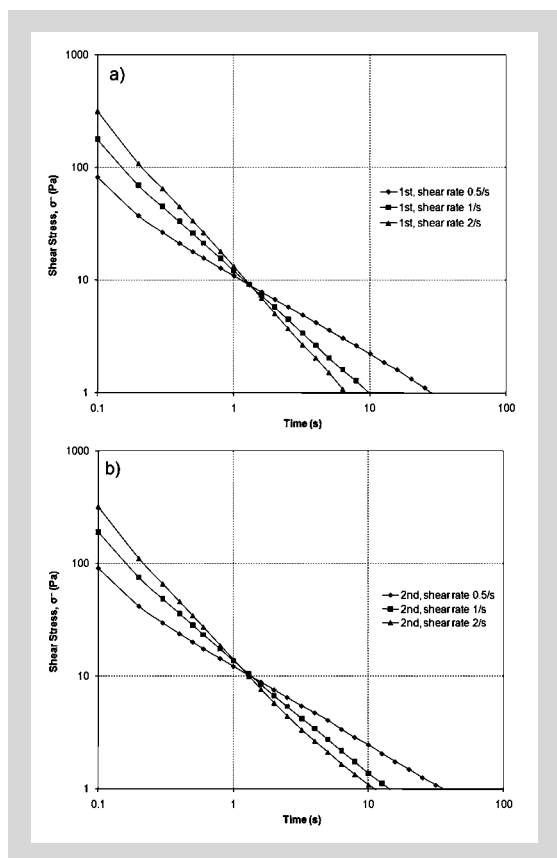
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Sample	Shear independent relaxation time (s)
PP/LCP	1.2
PP/LCP/SEBS-g-MA	5.0
PP/LCP/SEBS	2.0
PP/LCP/Silica	0.6
PP/LCP/m-Silica	0.9

Figure 9: Stress relaxation upon cessation of steady shear flow after: (a) first, and (b) second steps.

Table 3: Shear independent relaxation times obtained from first and second stress relaxation steps.

the viscosity ratio k , the particle radius R , the equilibrium interfacial tension γ° , and the matrix viscosity η_m . The relaxation time λ_D for the drop shape is given by the following relation [32]:

$$\lambda_D \sim f(k) \frac{R\eta_m}{\gamma^\circ} \quad (8)$$

The observed differences between shear independent relaxation times can be easily described by considering the reduction of both interfacial tension and droplet size in the presence of compatibilizer, and also the change in the viscosity in some cases as discussed before.

4 CONCLUSION

The results showed that melt linear viscoelastic properties and transient rheometry can be used in order to probe the effects of interfacial modification on polymer blends. It was found that SEBS-g-MA is more efficient in compatibilizing PP/LCP blend than SEBS, and while hydrophilic silica disperses in both matrix and LCP droplets, the hydrophobic silica compatibilizes the blend. The two step start-up/relaxation experiments demonstrated that although the droplet deformation and orientation are weak in these blend samples, the nematic orientation takes place irreversibly and shows a secondary stress growth only in first start-up step. Finally, the single intercept of stress relaxation curves at different shear rates is associated with a shear independent relaxation time of blend samples which can be originated from drop shape relaxation rather than a nematic structure relaxation.

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was performed for all samples and it was found that in all cases the intercept values for first and second stress relaxation occurs at the same time (Table 3). These results show that before cessation of steady shear flow in the first and second steps, the microstructures controlling this relaxation are the same. The higher shear independent relaxation time of SEBS-g-MA compatibilized blend compared to SEBS compatibilized blend, the lower shear independent relaxation time of PP/LCP/m-Silica in comparison to uncompatibilized blend, slower relaxation process (lower slope of curve) in second step for all blend samples, and also preceding stress growth results, all support this shear independent relaxation as drop shape relaxation rather than a nematic structure relaxation. In other words, as the structure of a nematic phase is dependent to the shear rate [25], the intercept of the relaxation curves and their slopes can be respectively related to drop shape and phases relaxations; and the differences between the relaxation processes in first and second steps is due to the different extents of nematic phase orientation.

During the interfacial relaxation process, the interfacial tension leads to long time relaxation processes which also affect the storage modulus in the low frequency region (Figure 4). These long time relaxation processes are associated with the mechanical relaxation of the dispersed phase [31]. The important physical parameters governing the relaxation processes are

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