Journal of Macromolecular Science, Part A
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597274

Fiber-Forming Blends of Polypropylene and Branched Polyethylene

A. Marcincin[a]; A. Ujhelyiová[a]; E. Zemanová[a]; T. Marcincinová[a]
[a] Faculty of Chemical Technology, Slovak University of Technology, Bratislava, Slovakia

To cite this Article Marcincin, A. , Ujhelyiová, A. , Zemanová, E. and Marcincinová, T.(1998) 'Fiber-Forming Blends of Polypropylene and Branched Polyethylene', Journal of Macromolecular Science, Part A, 35: 7, 1239 — 1247

To link to this Article: DOI: 10.1080/10601329808002114

URL: http://dx.doi.org/10.1080/10601329808002114

J.M.S.—PURE APPL. CHEM., A35(7&8), pp. 1239–1247 (1998)

FIBER-FORMING BLENDS OF POLYPROPYLENE AND BRANCHED POLYETHYLENE

A. Marcincin, A. Ujhelyiová, E. Zemanová, and T. Marcincinová
Faculty of Chemical Technology
Slovak University of Technology
812 37 Bratislava
Radlinského 9, Slovakia

ABSTRACT

In this paper, some results obtained at preparation of fibers from polypropylene and low-density polyethylene (LDPE) blends are presented. In the framework of this topic, the influence of the concentration of LDPE in PP on preparation conditions, rheological properties, mechanical and thermal properties, and structure of polymer blends and blended fibers was investigated.

Experimental value of the melt viscosity shows the negative declination from the additive ones. PP and LDPE form an incompatible system. Prevailing content of PE component has a positive influence on flow properties of the melt. Technological compatibility of fiber-forming PP-LDPE blend is very good at 60-80% of "non-fiber-forming" LDPE. Very good processing was reached when the dispersed PP phase formed the microfibrils in polyethylene matrix. In this case, the polyfibrillar structure of blended fibers was formed.

INTRODUCTION

The development of bicomponent polypropylene-polyethylene (PP-PE) fibers follows the improvement of some properties, mainly mechanical performance, elasticity, recovery properties, as well as thermobonding properties [1, 2, 3]. Polyolefin fibers modified by polar polymers can exhibit improved dyeability from

www.dekker.com

bath and better electrostatic properties [3, 4]. Blends of polymers represent a practical way for preparation of spun-dyed fibers and super microfibers [5, 6].

In the fiber industry, most of the polymer pairs when blended, demonstrate insufficient compatibility. Several conceptions were suggested [7] for the evaluation and prediction of mutual miscibility of polymers. Despite the similar chemical composition of PP and PE, the differences in stereoregularity, crystallinity, and supermolecular structure of the components prevent the creation of a homogeneous blend. From the practical point of view, the qualitative estimation of compatibility in terms of technological compatibility is usually sufficient and can be expressed e.g., by declination of some experimental parameters from additive values.

The polyfibrillar and sea-island types of bicomponent fibers are characteristic for fibers from polymer blends. In the first case, the dispersed phase forms long microfibrils in polymer matrix.

The polyfibrillar structure of fiber is formed under conditions of liquid drops flow in polymer medium. The stresses arising in the dispersion medium tend to deform and orient a drop. This process can continue at elongation of polymer stream or at the drawing process. According to Taylor's theory, the deformation of the drop in matrix can be expressed by the empirical equation [8].

$$D = W_e.(19K + 16) / (16K + 16)$$

where D is the deformation of the drop; $K = \eta_1/(\eta_2$, where η_1 is the viscosity of dispersed phase and η_2 the viscosity of medium; W_e = Weber number ($W_e = \eta_2.\gamma.r/\sigma$, where γ- shear rate, r - diameter of the drop, σ- interface tension).

The length of the deformed drop depends not only on deformation and orientation of the polymer blend, but also on the fracture of the drop during the elongation process.

The deformation E_c of the drop connected with its fracture (critical value of deformation) can be calculated by the formula:

$$E_c = (L - B) \ / \ (L + B)$$

where L and B are the major and minor axes of the deformed drops.

Generally, many authors confirmed the broad minimum of the critical deformation dependence (E_c (0.6) on the ratio K. It lies in the range of values of K $\equiv$ 0.1-1. For elongation flow, the E_c exhibits a lower values ($E_c \equiv 0.2$) at higher viscosity ratio (K $\equiv$1-5). For very low (under 0.001) or very high values of K, above 3.5, the deformed drop is stable in a homogeneous shear and elongation flow [9, 10].

The second condition for achieving the polyfibrillar structure is to reach the required degree of component interaction in the interphase layer (thermodynamic affinity). It has to be high enough for the transfer of stresses arising in the dispersion medium through the interface.

In this contribution, some results obtained in the preparation of fibers from polypropylene and low-density polyethylene (LDPE) blends are presented. In the framework of this topic, the influence of the concentration of LDPE in PP on preparation conditions, rheological properties, mechanical and thermal properties, and structure of polymer blends and blended fibers was investigated.

EXPERIMENTAL

For fiber from polymer blend PP-LDPE, the commercial types of PP and LDPE were used:

Polypropylene TATREN TI 902 (Slovnaft, a.s.),

$\rho_{23°C} = 900$ kg.cm^{-3}, MFI $= 27.8$ g/10 min.

LDPE Polyethylene BRALEN SA 200-22 (Slovnaft, a.s.),

$\rho_{20°C} = 916$ kg.m^{-3}, MFI $= 200$ g/10 min.

The PP-LDPE blends were prepared by the classical procedure comprising the following stages: (1) Homogenization of the polymer chips, and (2) Melting of the mixture in single-screw extruder equipment $\varnothing = 16$ mm at 230°C.

The samples of PP-LDPE fibers were prepared by means of model pilot plant unit with an extruder with diameter $\varnothing = 16$ mm at 180-240°C, the result being 154 m/min^{-1}. Linear density of the undrawn fiber was $T_{dt} = 600$ dtex, the drawing ratio $\gamma = 3$ at 80°C.

RESULTS AND DISCUSSION

The calculated ratios $K = \eta_1/\eta_2$ for PP-LDPE are given in the Table 1. The convenient conditions for preparation of the polyfibrillar structure of fibers with significantly deformed particles of dispersed phase in shear and elongation regime are suitable for low-molecular LDPE 200 mainly in the case when it forms a matrix phase. The values of K are higher enough when they are compared with the critical

TABLE 1. Dependence of K on Shear Stress τ for PP and LDPE ($K_1 = \eta_{PE}/\eta_{PP}$; $K_2 = \eta_{PP}/\eta_{PE}$)

	τ [kPa]	η_{PP} (230°C) [Pa.s]	η_{LDPE} (230°C) [Pa.s]	K_1	K_2
1	8.4	425	32	0.075	13.30
2	12.3	340	30	0.088	11.30
3	16.5	275	28	0.102	9.82
4	21.7	220	26	0.118	8.46

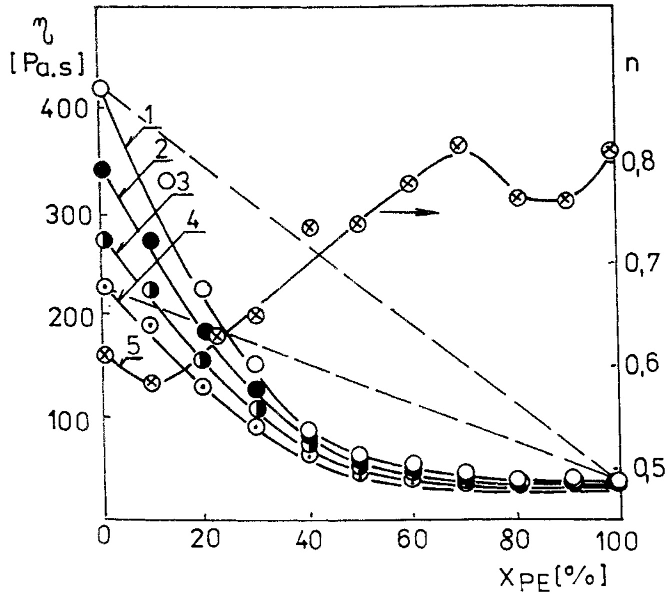


Figure 1. Dynamic viscosity (η) and Power law index (n) of the PP-LPDE blends τ [kPa] 1 - 8.4; 2 - 12.3; 3 - 16.5; 4 - 21.7.

values. They are higher than 2.0 or 3.5. On the other hand, when the polypropylene forms medium, the rheological properties of components do not permit the creation of long fibrils of dispersed LDPE phase. In this case, K values are close to the minimum value of K. The high K values (K ≅ 10) allows us to prepare blends with good deformation of disperse polypropylene phase in LDPE matrix at shear flow and also in the drawing process. At higher shear stress, the conditions for developing polyfibrillar blends are less suitable.

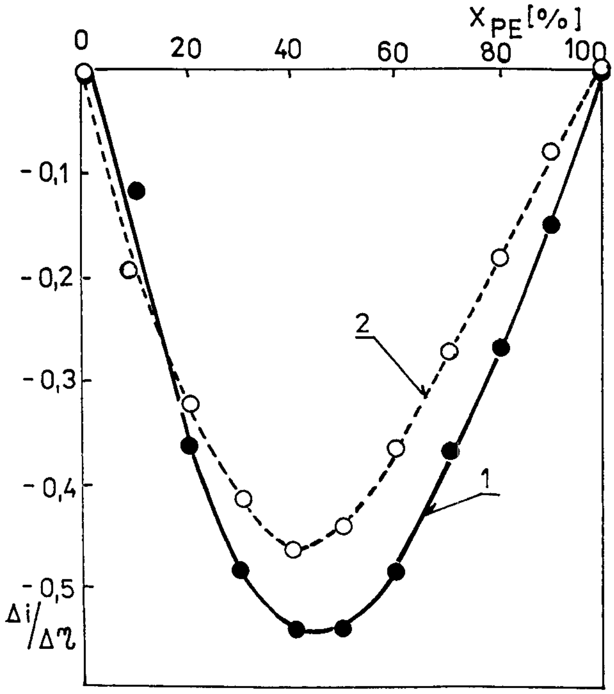


Figure 2. Deviation of the experimental viscosity of the PP-LPDE blends from additive values τ [kPa] 1 - 8.4; 2 - 21.7

The concentration influence of LDPE on viscosity of the PP-LDPE melt at 230°C at various shear stress is shown in Figure 1. From the dependence of viscosities on blend composition, the high negative declination of experimental values from the additive ones can be observed. These results reveal the nonsynergic behavior of the mixture. The blends PP-LDPE are incompatible.

The negative declination of experimental values of viscosity from the additive ones in dependence on blend composition, (given in Figure 2) is symmetrically shaped with the minimum at 40% LDPE in mixture. The minimum on the curves of viscosity declination, due to blend composition, is probably connected with the phase inversion. LDPE as a dispersion medium has a strong influence on rheological and other properties of blends or fibers. The power law index rises with the PE content in mixture and, at above 70% LDPE in mixture, its value is close to the index of LDPE itself. In all cases, it follows as a result of the rheological measurement, that the properties of individual components, both PP and LDPE, in melt of blend are significantly manifested.

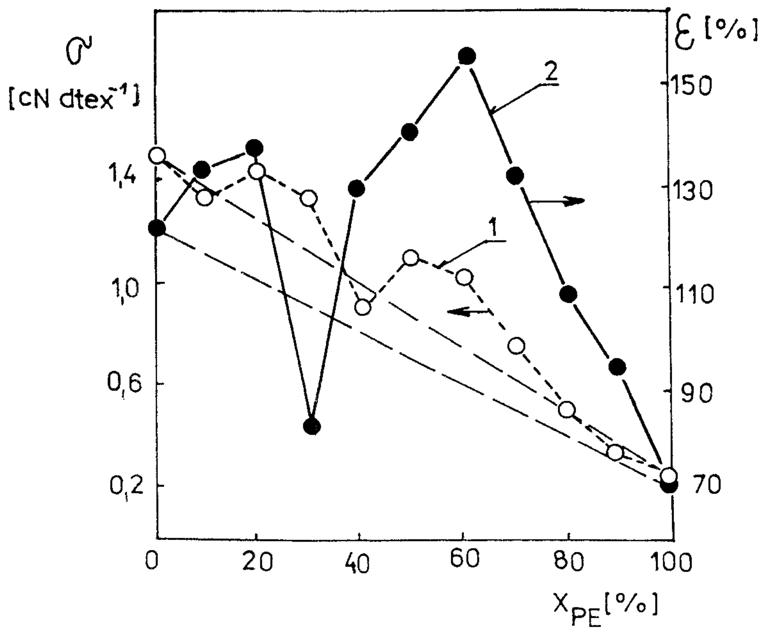


Figure 3. Tenacity σ (1) and elongation ε (2) of PP-LDPE fibers.

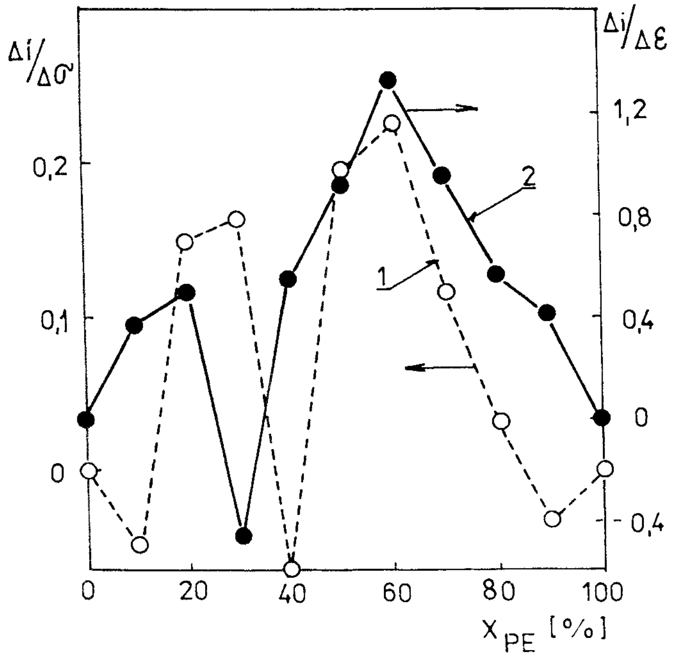


Figure 4. Deviation of tenacity σ (1) and elongation ε (2) of the PP-LPDE fibers from additive values.

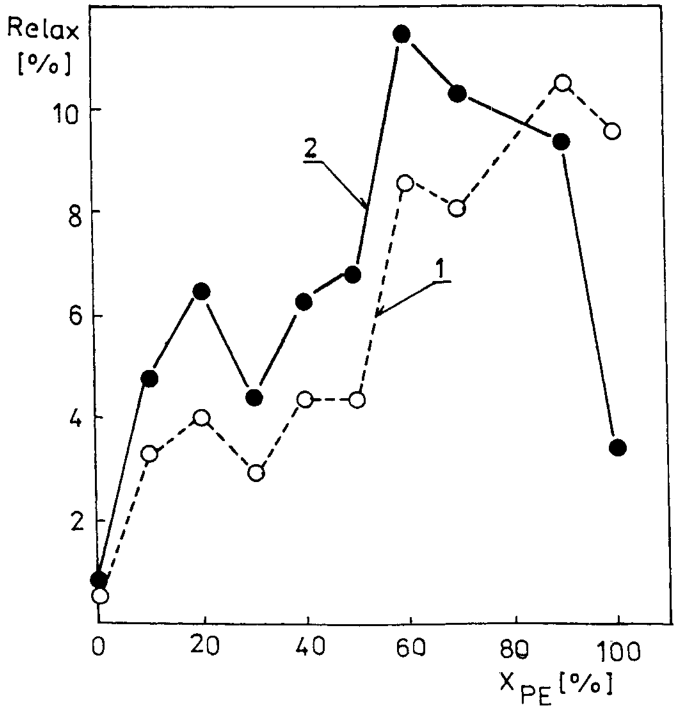
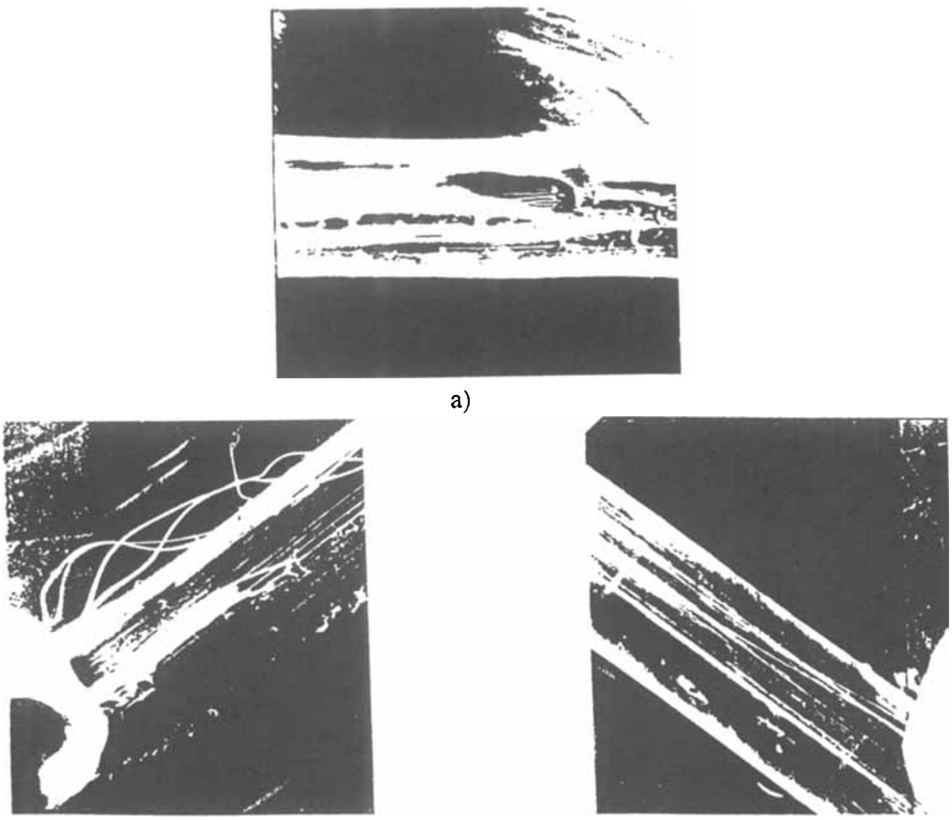


Figure 5. Relaxation of PP-PE fibers at 80°C (1) and at 80°C after 10 minutes (2).

Tenacity and elongation of PP-LDPE fibers are given in Figure 3. The tenacity of blended fibers decreases proportionally to the LDPE content in mixture. The positive declination of tenacity from the additive value can be seen at 20-30% and at 50-70% LDPE in PP. In those concentration regions, we can indicate the positive declination from the additive values also for elongation of blended fibers. The minimum tenacity and elongation of fiber at 30-40% LDPE in PP results probably from the phase inversion of component. This fact is clearly seen in Figure 4. There is the minimum on dependences $\Delta i(\sigma, \varepsilon)$ at 30-40% LDPE, as well as the maximum by a 20% increase in the range of 50-70% LDPE in mixture.

The relaxation of oriented fibers at 80 °C is given in Figure 5. Two regions of relaxation values were observed. Lower relaxation, when the continuous phase is PP, and a higher one, when the LDPE forms a matrix of blended fibers. The maximum values of relaxation are observed at 60-90% LDPE.

The creation of a polyfibrillar structure of PP-PE fibers was confirmed by microscopic analysis (Figure 6). The macrostructure of oriented fibers from PP-



a)

b)

c)

Figure 6. The polyfibrillar structure of fibers spun from polypropylene low density polyethylene blend.

Drawing ratio $\gamma = 3$

a) 100% LDPE b) 80% PP + 20% LDPE c) 30% PP + 70% LDPE

LDPE blends exhibits a fine microfibrils of PP phase within 60-80% LDPE in the mixture. A lower content of PE in the mixture does not form a regular and fine microfibrillar structure. Oriented microfibrils are absent entirely in LDPE fiber (Figure 6a). Despite the very good flow and deformation properties and homogeneous oriented structure of PP-LDPE fibers, the mechanical properties are relatively low because of weak interaction on the interface layer and low tenacity matrix phase LDPE.

CONCLUSION

Considering the theoretical prediction of the polyfibrillar blends formation, the fibers from polypropylene (low-molecular mass, low density polyethylene were prepared.

The experimental value of the melt viscosity shows the negative declination from the additive ones. PP and LDPE form an incompatible system. The prevailing content of PE component has a positive influence on flow properties of the melt.

PP phase improves the mechanical properties of LDPE within 20-30% and 60-80% in mixture.

Technological compatibility of fiber-forming PP-LDPE blend is very good at 60-80% of "nonfiber-forming" LDPE. Very good processing was reached when the dispersed PP phase formed the microfibrils in polyethylene matrix. In this case, the polyfibrillar structure of blended fibers was formed.

REFERENCES

[1] K. Schäfer, *Chem. Fiber Int.*, *45,* 116 (1995).

[2] R. Vogel, G. Schauer, G. Schmack, R. Beyreuther, and E. Meyer, *Chem. Fiber Int.*, *46*, 421 (1996).

[3] A. Marcincin, A. Ujhelyiová, and M. Kristofic, *Vlákna a Textil (Fiber and Textiles), 2*, 181 (1995).

[4] K. Ondrejmiska, *Vlákna a Textil (Fiber and Textiles), 1*, 11 (1994).

[5] T. V. Kalinskaja, S. G. Dobronevskaja, and ZA. Avrutina, *Okrasivanie Polimernych Materialov*, Chimija, Petersburg, 1985.

[6] M. Matsui, *Chemiefasern/Textilind., 43,* 223 (1993).

[7] D. J. David and T. F. Sincock, *Polymer, 33,* 4505 (1992).

[8] M. V. Tsebrenko, G. P. Danilova, A. Ja. Malkin, and J. Non-Newton, *Fluid Mech., 31,* 1 (1989).

[9] S. Torza, R. G. Cox, and S. G. Mason, *J. Coll. Interf. Sci, 38,* 395 (1972).

[10] C. D. Han, *Multiphase Flow in Polymer Processing,* Academic Press, New York, 1981.