Drawing Behavior of Polyethylene–Polypropylene Blends

INTRODUCTION

The purpose of this communication is to report upon an investigation into the drawing behavior of mechanical blends of polyethylene (PE) and polypropylene (PP). Regarding the tendency of both homopolymers to fibrillate and the importance of fibrillation in determining properties of the drawn product, particularly in directions perpendicular to the draw direction, it was hoped to establish the degree to which microfibrillation could be controlled by employing mixtures.

EXPERIMENTAL

The two homopolymers used in this study are both known to have good cold-drawing properties.[1–5] The PE was BP Rigidex 140-60 and the PP was ICI GYE 47. The blends were produced by mixing weighed quantities of granules in a Brabender Plastigraph internal mixer at approximately 190°C. The mixtures were compression-molded into plaques 1 mm thick at 170–190°C and rapidly cooled by running cold water through the press platens.

Some of the plaques appeared defective. One molded from 70 PE:30 PP contained transparent regions almost square in shape in a translucent matrix (Fig. 1). Differential thermal analysis (DTA) of transparent material showed that it contained a much higher proportion of PP than the matrix (Fig. 2). Another plaque molded from 70 PE:30 PP but at 190°C also showed segregation in parts, but contained sufficiently large visually homogeneous regions from which to cut test bars. Whenever possible, specimens were cut from regions free from the flow lines that were occasionally in evidence. DTA of streaky and of visually homogeneous regions cut from the same plaque showed no evidence for variation in composition.

Dumbbell specimens with a gauge length of approximately 20 mm and width 5 mm were stamped out of the plaques. All surface flaws were removed by polishing prior to drawing. Drawing was performed on an Instron 1026 tensile testing machine at a cross-head speed of 5 mm/min using a telescopic temperature chamber that permitted large cross-head movement. Open circuit heating was supplied by a fan heater controlled by a thyristor controller using the signal from a thermocouple placed adjacent to the center of the specimen. Drawing was continued to fracture, which was typically fibrous in appearance (Fig. 3).

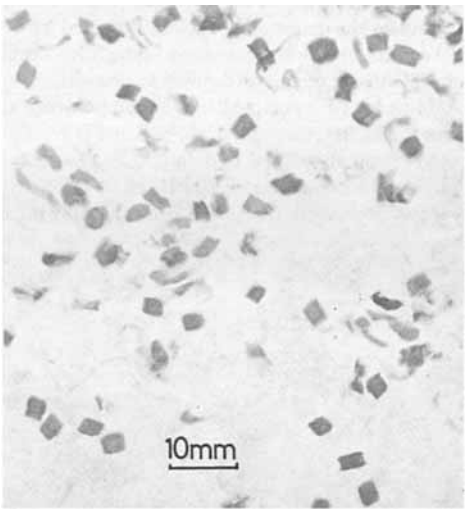


Fig. 1. Part of an as-moulded sheet of 70 PE:30 PP, showing transparent regions.

Journal of Applied Polymer Science, Vol. 26, 3515–3521 (1981)
 CCC 0021-8995/81/103515-07$01.00

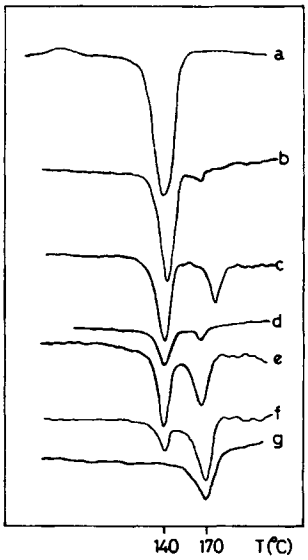


Fig. 2. DTA thermograms (arbitrary scale): (a) PE homopolymer; (b) 70 PE:30 PP: visually homogeneous region; (c) 70 PE:30 PP: transparent grain; (d) 50 PE:50 PP; (e) 30 PE:70 PP; (f) 10 PE:90 PP; (g) PP homopolymer.

Fragments of drawn specimens were mounted on stubs and gold-coated prior to examination in a Cambridge Instruments S600 Stereoscan using the secondary electron image.

RESULTS

Well-separated DTA endotherms corresponding to the individual homopolymers were obtained with most specimens, the exception being one 70 PE:30 PP specimen in which a single strong endotherm was obtained at a slightly higher temperature than the usual PE position, plus a very weak endotherm close to the PP position (Fig. 2). It is interesting to note that this result, consistent with a high degree of homogenization at the molecular level, was obtained with a sample having the same composition (70 PE:30 PP) as that in which gross phase segregation occurred.

It was found that the temperature for successful drawing varied with the composition. In principle, it would be possible to establish for each composition the temperature at which the highest draw ratio, the highest stiffness, or the highest strength of the product is achieved at a particular drawing speed, though this has not yet been attempted in detail. Therefore, the temperatures used may not have been optimal, though in the cases of 50 PE:50 PP and 30 PE:70 PP a temperature reduction of 5–10° was found to result in premature fracture during the drawing operation. The drawing

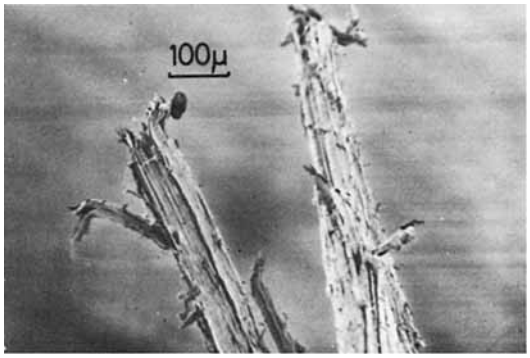


Fig. 3. Fractured end of a 10 PE:90 PP specimen drawn at 80°C.

TABLE I

Composition (PE:PP)	Draw temperature (°C)	Areal draw ratio
70:30	100	—
70:30	90	—
70:30	80	—
50:50	125	1.1
30:70	114	10.4
30:70	107	7.2
30:70	107	3.7
10:90	80	10.3
10:90	70	8.3
10:90	60	9.1

temperatures used for successful drawing experiments are shown in Table I. Also shown are draw ratios, estimated from areal reduction measurements. The results of the microstructural examination is most conveniently presented for each material in turn.

PE: Many of the important microstructural features of highly drawn PE have been reported before.[5] One striking feature that has not previously been emphasized is the formation of a surface layer that has a quite different appearance from the interior (Fig. 4). This surface layer has striations running parallel to the draw axis and fractures easily parallel to this direction to reveal, in the case of Rigidex 140-60, a highly fibrillated interior.

70 PE:30 PP: Several distinct characteristics were found on specimens with this composition. In the specimen drawn at 100°C the formation of a surface layer was again in evidence, part of it having become detached to reveal an underlying microstructure with braided appearance (Fig. 5).

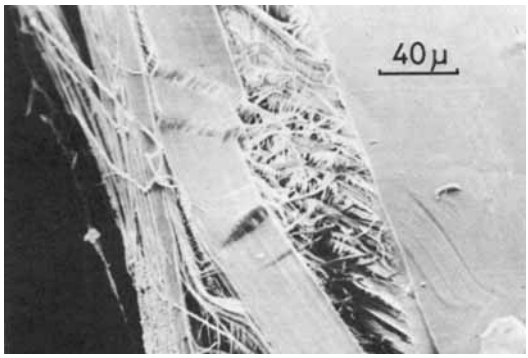


Fig. 4. PE homopolymer drawn 25× at 75°C with fibrils drawn across a crack running parallel to the specimen axis.

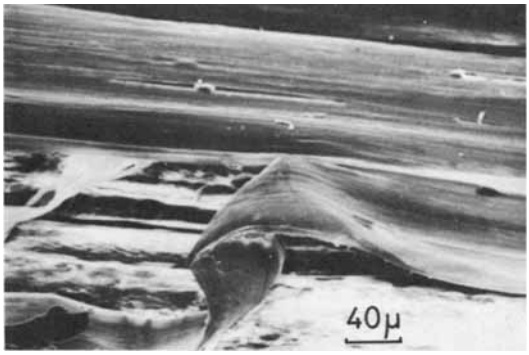


Fig. 5. Surface peeling on the 70 PE:30 PP specimen drawn at 100°C.

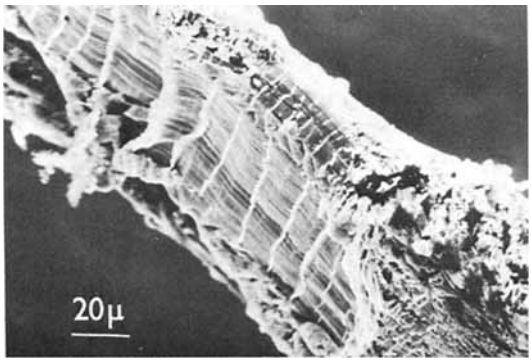


Fig. 6. Region near the fractured end of the 70 PE:30 PP specimen drawn at 100°C.

The nucleation of another axial fracture in the surface layer appears to have begun at a flaw in an adjacent area. The appearance of this specimen is reminiscent of the peeling observed by Konopasek and Hearle on Kevlar aramid fibres.[6] In another part of the same specimen, nearer to the site of fracture, a layered appearance was revealed (Fig. 6).

No smooth surface layer was found on the specimen drawn at 80°C (Fig. 7), and the surface of the specimen drawn at 90°C had an appearance intermediate between those shown in Figures 5 and 7. The lack of uniformity of cross section of these specimens made it impossible to estimate the draw ratio.

50 PE:50 PP: This specimen showed a very open structure with large voids oriented parallel to

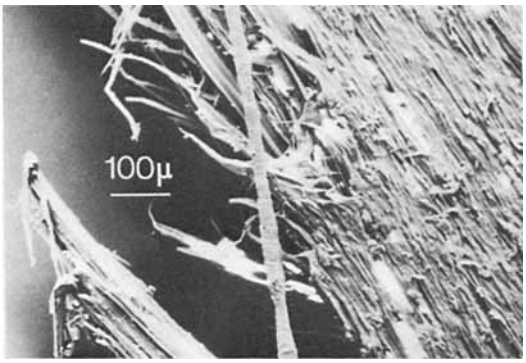


Fig. 7. Part of the 70 PE:30 PP specimen drawn at 80°C.

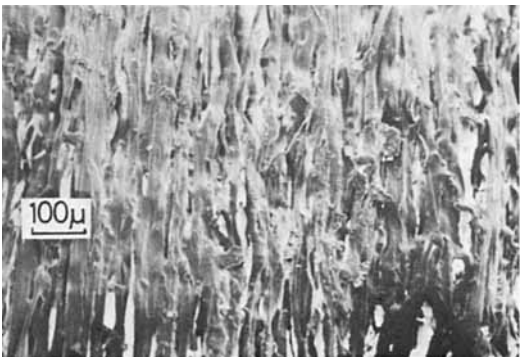
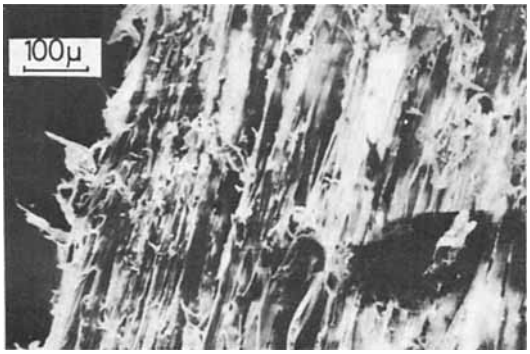


Fig. 8. Voided structure of 50 PE:50 PP drawn at 125°C.

(a)



(b)

Fig. 9. 30 PE:70 PP specimens drawn at (a) 114°C and (b) 107°C.

the draw direction (Fig. 8). This accounts for the very small change in cross-sectional area (the specimen actually became thicker though narrower) and the consequent low estimation of the draw ratio which was far smaller than would have been obtained if a method based on the extension of the necked region had been available. The drawn region felt spongy.

30 PE:70 PP: The specimen drawn at 114°C had a far less ragged appearance than those drawn at 107°C in which many short microfibrils were found to protrude from the surface (Fig. 9).

10 PE:90 PP: Rather course fibrillation was produced on drawing at 80°C (Fig. 10) and in some areas fibres were seen to be drawn across axial cracks, similar to previous observations on PE (Fig. 3 of Ref. 5). Striations perpendicular to the draw direction, less prominent than those parallel to it, are visible on the specimen drawn at 70°C (Fig. 11). A voided structure was found to be produced by drawing at 60°C, (Fig. 12), though the separation of the fibrils was not as great as for the 50 PE:50 PP specimen and did not have such a marked effect on the areal draw ratio.

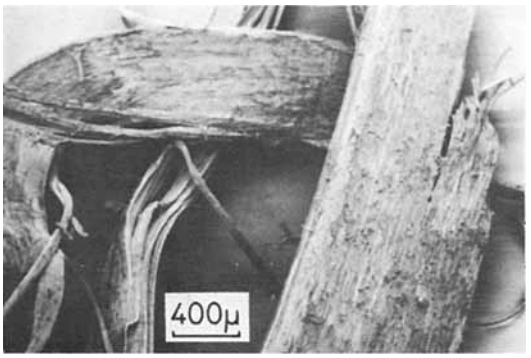


Fig. 10. Part of the 10 PE:90 PP specimen drawn at 80°C.

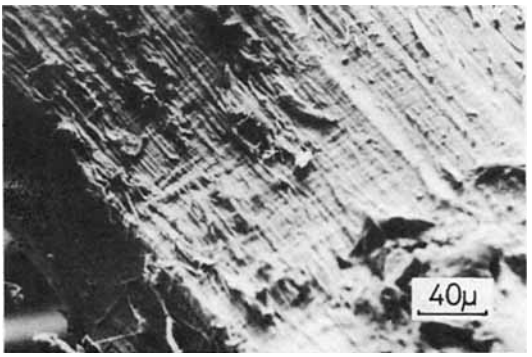


Fig. 11. Part of the 10 PE:90 PP specimen drawn at 70°C.

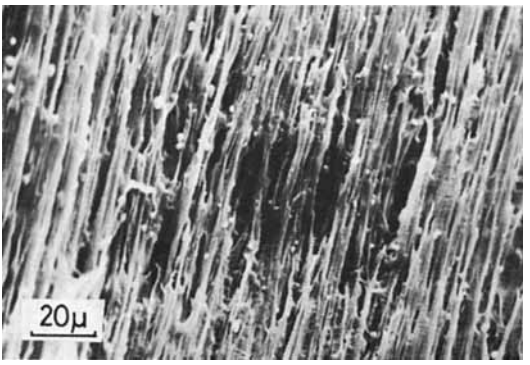


Fig. 12. Part of the 10 PE:90 PP specimen drawn at 60°C.

CONCLUSIONS

It has been established that large draw ratios can be obtained with mechanical blends of PE and PP. Fibrillation is not as uniform in the blends as with PE homopolymer, and all the compositions tested produced coarser fibrillation than the homopolymer. The fibrils produced from blends have nodules or surface peeling defects; such structures are absent in the PE homopolymer fibrils, which appear to have very extensive lengths of uniform cross section. Extensive voiding occurred in the specimen containing equal amounts of PE and PP, with large voids aligned parallel to the fibrils.

Note added in proof: The authors regret that a long publication lag has significantly reduced the topicality of this contribution. We wish to draw attention to several relevant publications on blends of PP and linear PE that have appeared since we completed this work[7–12] and also to the interesting studies of PE/PP blends crystallized in solution under shear to produce strongly oriented structures.[13,14]

References

1. G. Capaccio and I. M. Ward, *Polymer*, **15,** 233 (1974).
2. G. Capaccio and I. M. Ward, *Polymer*, **16,** 239 (1975).
3. J. B. Smith, G. R. Davies, G. Capaccio, and I. M. Ward, *J. Polym. Sci., Polym. Phys. Ed.*, **13,** 2331 (1975).
4. D. L. M. Cansfield, G. Capaccio, and I. M. Ward, *Polym. Eng. Sci.*, **16,** 721 (1976).
5. G. J. Sandilands and J. R. White, *J. Mater. Sci.*, **12,** 1496 (1977).
6. L. Konopasek and J. W. S. Hearle, *J. Appl. Polym. Sci.*, **21,** 2791 (1977).
7. N. Alle and J. Lyngaae-Jørgensen, *Rheol. Acta.*, **19,** 94 (1980).
8. N. Alle and J. Lyngaae-Jørgensen, *Rheol. Acta.*, **19,** 104 (1980).
9. R. Greco, G. Mucciariello, G. Ragosta, and E. Martuscelli, *J. Mater. Sci.*, **15,** 845, (1980).
10. R. Greco, G. Mucciariello, G. Ragosta, and E. Martuscelli,. *J. Mater. Sci.*, **16,** 1001 (1981).
11. A. J. Lovinger and M. L. Williams, *J. Appl. Polym. Sci.*, **25,** 1703 (1980).

12. W. Wenig and K. Meyer, *Colloid Polym. Sci.*, **258,** 1009 (1980).
13. A. Coombes, C. G. Cannon, and A. Keller, *J. Polym. Sci., Polym. Phys. Ed.* **17,** 1957 (1979).
14. C. S. Brown, P. J. Barham, and C. G. Cannon, *J. Polym. Sci., Polym. Phys. Ed.* **19,** 1067 (1981).

P. ROBSON
G. J. SANDILANDS
J. R. WHITE

Department of Metallurgy and Engineering Materials
University of Newcastle upon Tyne
Newcastle upon Tyne, NE1 7RU, United Kingdom

Received January 11, 1979
Accepted June 11, 1981