PLASTIC DEFORMATION OF POLYAMIDE 6/POLYPROPYLENE-g-ACRYLIC ACID BLENDS.

Tomasz Kazmierczak[1], Nelly P.Krasnikova[2], Andrzej Galeski[1]* and Mariano Pracella[3]

1. Centre of Molecular and Macromolecular Studies, Polish Academy of Sciences, 90-363 Lodz, Poland
2.on leave from Institute of Petrochemical Synthesis Russian Academy of Sciences, Moscow, Russia
3.Centre of Studies of Macromolecular Materials, CNR, Pisa, Italy

SUMMARY:Two means of plastic deformation were applied to the polyamide 6/polypropylene-g-acrylic acid blends (in two composition 8:2 and 2:8): drawing and plane strain compression in a channel die. X-ray diffraction pole figures,density measurements, SEM, DMTA were applied for studying the structure and properties of oriented blends. It is concluded that interfaces between blends components are weak elements of the blends even in presence of compatibilizing action of PP-g-AA.

Introduction

Compatibilized blends differ from blends of incompatible polymers, apart from more discrete dispersion of minor component, mainly by the structure and properties of the interface between components. Usually the achieved toughness of well compatibilized blends allows for their large plastic deformation. In plain crystalline polymers the elementary mechanisms of plastic deformation are crystallographic slips. However, in simple drawing the cavitation obscures the real crystallographic mechanisms [1]. The origin of cavitation is mechanical misfit between stacks of crystalline lamellae. In polymer blends there is another source of cavitation: interfaces between components.

The aim of this work is to determine wether the basic mechanisms of plastic deformation of crystalline are crystallographic in nature and consider the influence of cavitation on the process of plastic deformation. The important goal is also to assess the way in which the interface between components deforms during plastic deformation.

Two means of plastic deformation were applied to the polyamide 6/polypropylene-g-acrylic acid blends (PA 6/PP-g-AA): drawing and plane strain compression in a channel die. Drawing with no constraints is readily producing cavitation in polymers while the compressive component in channel die prevents for cavitation.

Experimental

Blends in composition 8:2 and 2:8 were prepared in a Brabender single mixing screw

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measuring extruder by three-fold mixing. For preventing excessive degradation 0.3% of Irganox 1010 was added to the dry blend before blending. Samples were then carefully dried at 105°C for several hours. The samples for drawing were prepared in the form of 1 mm thick compression molded film from which oar-shaped tensile specimens were cut. The samples for channel die were in the form of 10 mm thick plates obtained also by compression molding. Drawing was carry out in the environmental chamber of an Instron machine while channel die compression in the setup described in details elsewhere [2]. The deformation in both cases was performed at 95°C with the rate of 5 mm/min and stopped when the samples showed the engineering strain of approx. 4.0 (true strain ~1.4).

X-ray diffraction pole figures were applied for studying the texture of obtained samples according to procedure described in other our papers [3]. Density measurements were used for the detection of cavitation while SEM was employed to visualize the cavities. Samples for SEM were fracture in LN_2 and covered with thin layer of gold. Other techniques like DSC and DMTA were used to characterize further the structure and properties of oriented blends.

Results and Discussion

Table 1 shows the change in density due to different mode of plastic deformation.

Table 1 Densities of drawn and channel die compressed blends of polyamide 6 and polypropylene grafted with acrylic acid. True strain of all samples around 1.4.

Composition	Drawn samples	Compressed samples
PA6/PP-g-AA 8:2	1.044 g/cm^3	1.096 g/cm^3
PA6/PP-g-AA 2:8	0.948 g/cm^3	0.982 g/cm^3

From the density and also from SEM examination of deformed samples it is evident that during drawing significant amount of cavitation is preferentially produced at the interfaces between components while in the channel die compression the cavity formation is greatly suppressed. The effect is especially well seen in SEM micrographs of samples viewed from perpendicular direction to drawing or flow as it is demonstrated in Figs.1a and b.

Observations at other directions reveal an important feature of polyamide 6 inclusions in polypropylene rich blends which are almost undeformed in case of drawing while significantly deformed but less than the overall strain of the blend during channel die compression.

Polypropylene inclusions in polyamide 6 rich blends are deformed differently: in the case of channel die compression polypropylene inclusions are flatten in load and elongated in flow directions while in the case of drawing their shape resembles ellipsoid.

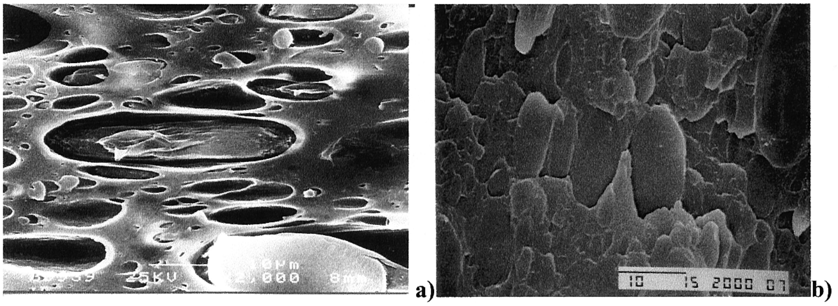

Fig. 1 SEM images of surfaces of polyamide 6/polypropylene-g-acrylic acid 8:2 blend deformed to true strain of 1.4 and fractured in liquid nitrogen. View from the direction perpendicular to drawing in case of drawn sample (a) and along loading direction in case of channel die compressed sample (b).

Texture analysis based on pole figures for (002) crystallographic planes for polyamide 6 and (110), (040) (060) and (-113) crystallographic planes for polypropylene shows that in the cases of both 8:2 and 2:8 blends the matrix polymers are strongly oriented: in drawing the texture resembles fibrous texture while in channel die the texture is rather single crystal similar to texture obtained for respective plane polymers. The exemplary pole figures of deformed blend obtained by x-ray diffraction are shown in Figs.2

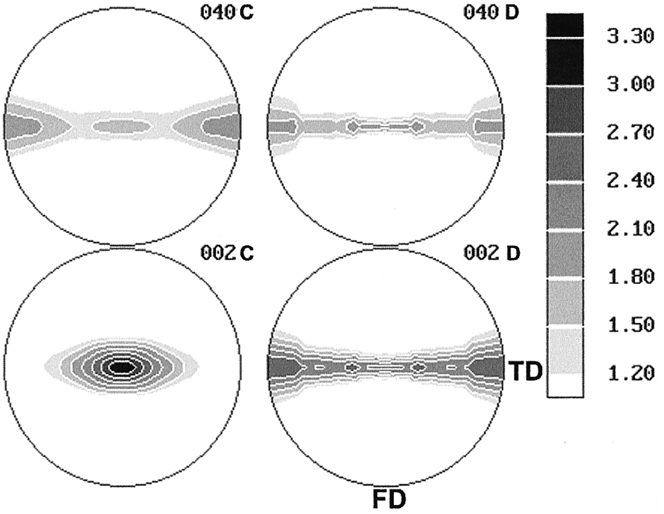

Fig. 2 Exemplary pole figures for crystallographic planes (040) of polypropylene and (002) of polyamide 6 for drawn and channel die compressed samples of the blend composed of 80% polyamide 6 and 20% of polypropylene-g-acrylic acid.

In PA 6/PP-g-AA 2:8 blend the dispersed polyamide inclusions are almost not oriented during drawing while only slightly in channel die compression. In the blend with majority of polyamide the dispersed inclusions of polypropylene-g-acrylic acid are deformed during drawing slightly less than the polyamide matrix and also resembles fibrous texture. In channel die compression the texture of the dispersed polypropylene component assumes, similarly to the matrix, sharp single crystal texture as it can be concluded from clustering of orientations of (-113) and (040) normals. The observed clustering of orientation suggests that during compression of the blends in a channel die the crystalline phase of both blend components are subjected to the same crystallographic slips as plain components compressed in a channel die [4 , 5]: polypropylene to (110) [001] chain slip and while polyamide 6 to (100)[010] chain slip as well to (100)[001] transverse slip.

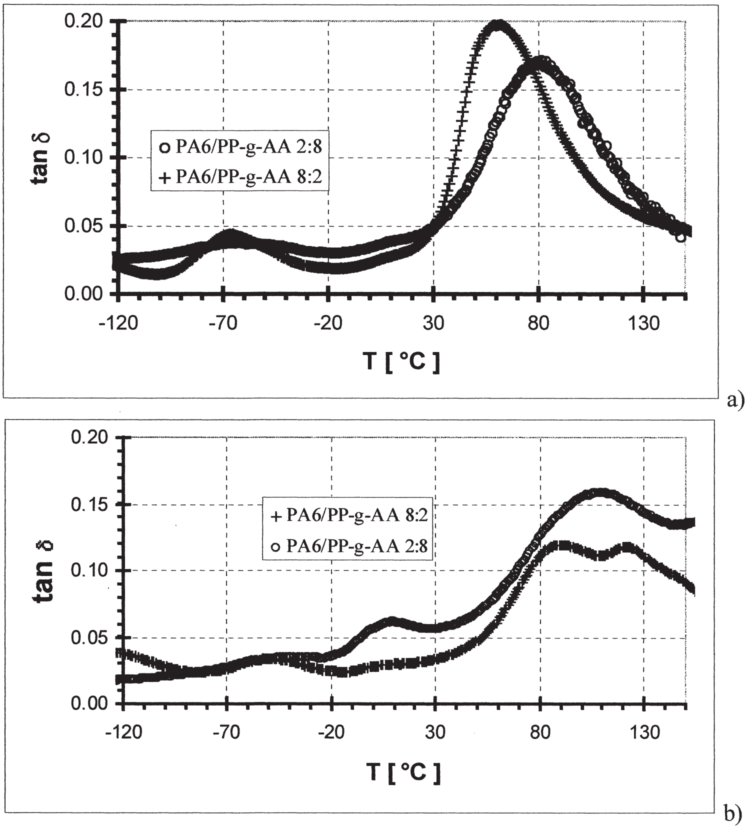

Fig. 3 Mechanical tanδ vs. temperature obtained in bending of oriented polyamide 6/polypropylene-g-acrylic acid blends: 8:2 and 2:8 compositions. The samples were oriented by drawing (a) and by compressed in a channel die b).

In Fig.3 the DMTA tanδ vs. temperature is plotted obtained in a bending mode. It is seen that α relaxation peaks for polypropylene and polyamide 6 are dominant in the spectrum. In both compressed samples the peaks are lower and broad with the peak at 110°C and double peak at 90°C and 120°C for polyamide and polypropylene rich blends, respectively. In drawn samples the α relaxation culminate at much lower temperature, at 60°C and 80°C for polyamide 6 and polypropylene rich blends, respectively.

Conclusions

It is evident that the interfaces between components are not strong enough in drawing to transfer stresses sufficient to deform dispersed polyamide in 2:8 blend but adequate to transmit the deformation to polypropylene dispersed component in 8:2 blend. In channel die compression the deviatoric stresses are transferred more efficiently to inclusions especially in the case of dispersed PP-g-AA . It is concluded that the interfaces between blends components are weak elements of the blends even in the presence of compatibilizing action of PP-g-AA.

The shift to lower temperature and intensified tanδ peaks for drawn samples can be attributed to severe destruction of crystals of polyamide 6 and polypropylene due to cavitation occurred during drawing and also to the formation of many new surfaces of cavities around inclusions.

References

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