Injection molding of iPP-DMDBS systems

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Introduction

Injection molding is a production process to manufacture large amounts of products in a short time. Nucleating agents, e.g. the sorbitol derivative DMDBS, are often added to isotactic polypropylene (iPP) to accelerate processing, altering the crystal structure and the properties of the product.

Material and methods

Materials

A homopolymer (Borealis HD120MO, $M_w = 365$ kg/mol, $PDI = 5.2$) was compounded with DMDBS (Millad 3988, 0.3, 0.7 and 1.0wt%). The phase diagram of the blends were determined using DSC and rheometry (*Fig. 1*). Three temperature regions are recognized: In region I, iPP and DMDBS form a homogeneous solution. In region II, upon cooling, DMDBS phase separates into fibrillar crystals. Further cooling, into region III, leads to crystallization of iPP. Upon heating, the transition temperatures between the different regions shift towards higher temperatures (thermoreversibility), giving rise to a temperature window in Region I, in which DMDBS crystals survive (*Fig. 1*, blue area).

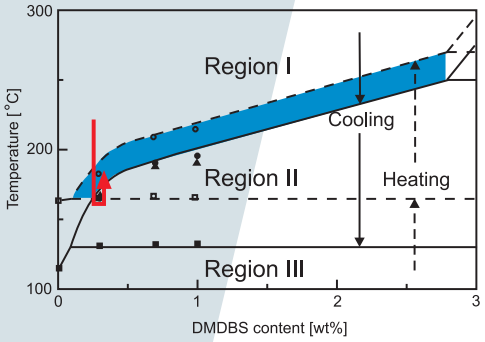

Figure 1 *Phase diagram of the iPP-DMDBS system. solid line: cooling, dashed line: heating.*

Methods

A capillary rheometer is used as an injection unit. The morphology of the rectangular strips (2x12x135 mm) is studied using optical microscopy (OM) for layer identification and X-ray diffraction (SAXS/WAXD) for determining crystallinity, crystal phases and lamellar thickness.

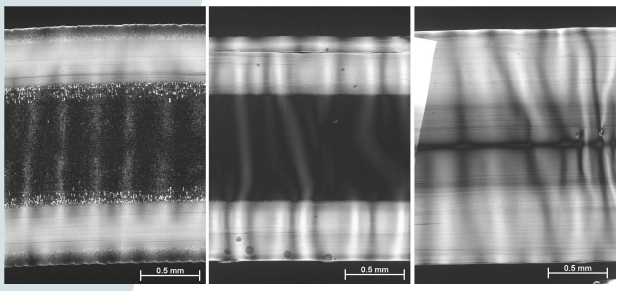

Figure 2 *OM micrographs (cross-section). Pure iPP (left), 0.3wt% DMDBS (mid), 0.3wt% DMDBS, thermal treatment (right).*

Results

Fig. 2 shows the OM micrographs of a pure iPP sample (left) with a concentration of 0.3wt% (mid) ($T_{melt} = 220°C$, $v_{inj} = 20mm/s$ for $t = 4s$). Both samples show the commonly observed oriented skin - isotropic core morphology with no change in the skin layer thickness, although the presence of DMDBS can lead to the formation of a highly oriented iPP morphologies [1]. By applying a thermal treatment to the melt before injection (*Fig. 1*, red arrow) it is possible to create oriented iPP structures over the full thickness of the sample (*Fig. 2* (right)).

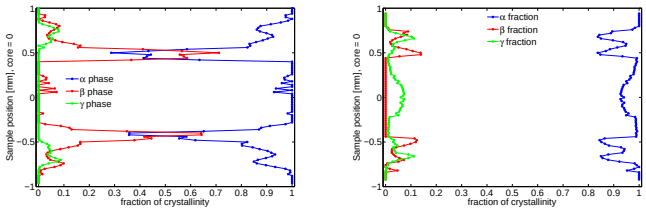

Figure 3 *The amount and distribution of iPP crystal phases: pure iPP (left) and with 0.3wt% (right).*

The overall crystallinity is constant over the thickness for all samples ($X_{c,iPP} \sim 67\%$) with an increase of $\sim 5\%$ when DMDBS is added. *Fig. 3* (left) shows the distribution and amount of crystal type for the pure iPP sample. Due to strong orientation, the β phase dominates in the shear layer. DMDBS strongly suppresses its formation (*Fig. 3* (right)) and, more important, the amount and distribution of the crystal types is independent of the amount of DMDBS and the thermal treatment. The crystal thickness (L_p) in the skin layer is unaffected by the DMDBS (*Fig. 4*); in the core L_p increases with an extra contribution of the orientation of the DMDBS fibrils.

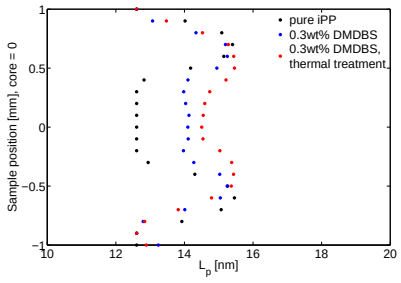

Figure 4 *Lamellar thickness over the thickness for pure iPP (black), 0.3wt% DMDBS (blue) and 0.3wt%, thermal treatment (red).*

Conclusions

By the addition of DMDBS *AND* the proper thermal treatment, products with oriented structures over the full thickness can be obtained. Big differences are observed in the morphology (crystal type, L_p), changing the properties of the product.

References:

[1] BALZANO, L. ET AL.: *Macromolecules, accepted* (2007)

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