Crystal orientation on a substrate : a new route towards toughness?

Crystal Orientation on a Substrate: a New Route Towards Toughness?

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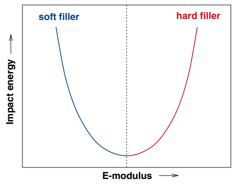
/Introduction

Most semi-crystalline polymers are ductile, but start to behave brittle under severe conditions: high deformation rate and low temperature. It is known that the impact toughness of semi-crystalline polymers can both be increased by addition of rubber particles as well as certain hard filler particles.

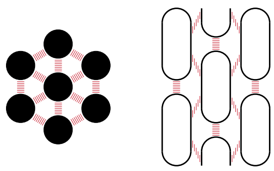
Advantage of system with hard filler compared to rubber filler:

- Increased stiffness
- No influence T_g rubber phase



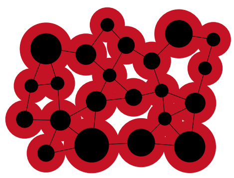
Toughening mechanism

Recently a toughening mechanism for these heterogeneous semi-crystalline polymer systems was postulated by A.S. Argon (MIT) [1-3]. It is based on the idee that an interface is formed around the inclusions (rubber or hard filler), which consists of preferentially oriented crystalline lamellae, having a reduced plastic shear resistance in the crystal planes parallel to the filler surface.



Upon cavitation or debonding of particles → large shear deformation of ligaments between particles

If oriented lamellae bridge between particles → low shear resistance behaviour percolates throughout structure and toughness is enhanced.

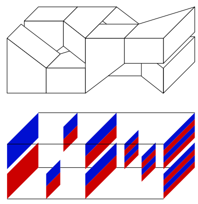


Objective

The goal is to verify this toughening mechanism. The first step is to find the existence and mechanical behaviour of this anisotropic crystal oriented layer.

/Materials and Methods

Using a multiflux static mixer sub-micron multi layer systems can be made consisting of alternating layers of a semi-crystalline polymer (HDPE) and a substrate polymer (SEBS & SBS):

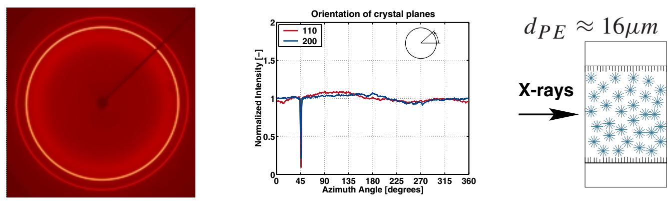


5 to 10 mixing elements
⇓
64 to 2048 layers
⇓
Layer thickness: 16 μm to 0.2 μm

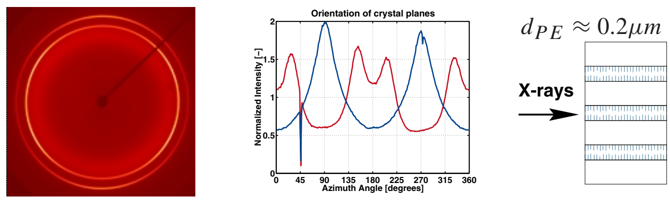
The crystal orientation was investigated by X-ray diffraction and Transmission Electron Microscopy.

/Results

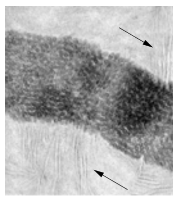
Wide Angle X-ray Diffraction patterns:



- Thick HDPE layers show no crystal orientation → isotropic spherulites



- Thin HDPE layers show orientation of the 200 (∥ to surface) and 110 ($\pm 30°$ to 200) crystal planes → lamellae ⊥ to surface



TEM confirms lamellae orientation in HDPE near the substrate.

Conclusion: So far the results support the postulated toughening mechanism.

/Future Work

- ☐ Determine thickness of crystal oriented layer more accurate
- ☐ Exploitation towards other materials
- ☐ Determine mechanical behaviour of anisotropic crystalline layer

/References:

[1] Muratoglu, O.K., Argon, A.S., Cohen, R.E. and Weinberg, M. *Polymer, vol. 36, p921-930, 1995.*

[2] Bartczak, Z., Argon, A.S., Cohen, R.E. and Weinberg, M. *Polymer, vol. 40, p2331-2346, 1999.*

[3] Bartczak, Z., Argon, A.S., Cohen, R.E. and Weinberg, M. *Polymer, vol. 40, p2347-2365, 1999.*