Title:

Interaction between molecular composition and blown film processing conditions of Polyethylene

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Reference 1: 1. Kearns, K., Scherzer,J., Rutledge, G.C., Measuring Flow-Induced Crystallization Kinetics of Polyethylene After Processing. Macromolecules 54, 5 2101 (2021)
Reference 2:
Reference 3:
Reference 4:
Reference 5:
Reference 6:
Reference 7:
Reference 8:
Reference 9:
Reference 10:
Reference 11:
Reference 12:

Images:

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Abstract:

Introduction

Polyethylene makes about 30% of all plastics used in the world. Half of it is processed as film or sheet, requiring the best mechanical properties to guarantee its performance. Properties like dart impact or tear resistance are the result of the molecular composition of the polymer and the processing conditions, which together provide a certain morphology. The effect of molecular architecture on intrinsic mechanical properties is relatively well known. However, it is observed that properties of certain families of PE are more sensitive than others to changes in processing conditions. To understand this effect, resins with the same overall molecular weight and crystallinity, but different molecular composition, have been subjected to varying blown film extrusion conditions. The objective is to determine how composition heterogeneity makes the resin sensitive to changes in processing.

Experimental

Two polyethylene resins have been chosen. One is a heterogeneous, Ziegler-Natta catalysed ethylene/1-octene copolymer. The second is a homogeneous, metallocene catalysed ethylene/1-hexene copolymer. Their composition has been characterized by gel permeation chromatography and by iCCD (for comonomer distribution). Crystallization kinetics has been followed by Fast Scanning Calorimetry. Films (50μ) have been produced in a lab-scale blown film line at 22.5 kg/h and also in an industrial scale blown film extrusion line at between 75 and 275 kg/h. Film properties have been measured according to ASTM methods.

Results and Discussion

Dart impact resistance for the ZN-LLDPE varies from 310 to 340g, while for the m-LLDPE varies from 700 to 1050g, for four widely different extrusion conditions. The difference in the average values is related to the probability of tie-chains between crystals. Once the melt exits the die, chains tend to orient and simultaneously relax while temperature quickly decreases. Flow-induced crystallization takes place to an extent depending on the straining of the melt and the capacity of the chains to relax [1]. ZN-LLDPE contains long relaxation times species that align with the flow at relatively high temperature, and favour flow-induced crystallization, faster than m-LLDPE. Crystallization rate is measured to be one order of magnitude faster for ZN-LLDPE than for m-LLDPE.

The crystallization, and probably nucleation, process is so strongly favoured for ZN-LLDPE that it is very little affected by changes in flow rates or cooling rates. This stabilizes the resulting structure and therefore film properties. On the other hand, m-LLDPE, which does not contain the molecular types that induce crystallization, will be more dependent on specific conditions to start the process. At low flow rates and slow cooling, m-LLDPE's chains will be able to relax much more than ZN-LLDPE, resulting in different crystal morphology and lower orientation, and therefore physical properties.