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Short Communication

Fracture behaviour of a polypropylene film

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ABSTRACT

Ageing of polymers results from structural modifications at the molecular scale and kinetic modelling must be elaborated from analysis of the phenomenon at this scale. However, the change of mechanical properties results from modifications of structure at larger scale, especially the macromolecular scale (chain scission, crosslinking) and or at the macroscopic scale (skin-core structure linked to a superficial attack of the material).

The effect of photoageing on the behaviour of isotactic polypropylene films was studied on samples of weight average molar mass M_w = 270 kg mol^{-1}. The influence of photoageing on the fracture toughness was examined by using the Essential Work of Fracture (EWF) method. Complementary characterization was performed by FTIR, uniaxial tensile testing. In conclusion, EWF tests performed appear as an interesting method to characterize the influence of structural factors on the fracture properties of polypropylene.

1. Introduction

Polypropylene (PP) application is automotive parts, fibers for outdoor exposure, etc. have raised up an impressive amount of literature. It is now well known that this polymer is intrinsically reaction towards radical oxidation, even at ambient temperature, owing to the presence in the monomer unit, of easily abstractable tertiary CH bonds.

This process can be described, at least in a first approximation by the standard mechanistic scheme (Fig. 1).

Some kinetic properties of such "closed-loop" schemes, in which the reaction generates its own initiator (hydroperoxide), have been investigated in 1950 (Tobolsky et al.) and revisited in 2000 [1].

Schematically, the reaction displays an induction time of which the duration is inversely proportional to the initiation rate constant. In the case of photoageing, this latter is generally high, so that the induction period is short (for an unstabilized PP sample) or even inexistent, but the "closed-loop" character remains observable by some autoaccelerated shape of kinetic curves.

Indeed, the induction period can be considerably increased by pigments or UV absorbers (which decrease the photoinitiation rate by screen effect) or by radical scavengers such as hindered amines (HALS) [2].

Hydroperoxide photolysis leads primarily to highly reactive PO° and OH° radicals, which can rapidly abstract hydrogens to give P° radicals, but a very important characteristic of PO° radicals undergo a rearrangement easily by β scission leading to a chain scission. There is a large consensus on the fact that this latter is responsible for embrittlement. This latter occurs suddenly (when it is characterised by tensile testing), without significant changes of modulus or yield stress, at a very low conversion of the degradation process [3].

The sudden character of embrittlement indicates, no doubt, the existence of a critical structural state, but the exact nature of this critical state remains unclear: It could be a critical value of the molar mass, presumably linked to the entunglement density in the amorphous phase; a critical value of the tie chains (interconnecting crystalline lamellae) concentration, or a critical value of the crystallinity ratio X_c or, rather a critical value of the interlamellar distance l_a [4]. As a matter of fact, chain scission in the amorphous phase induces chemicrystallization, l_a e.g. induces an increase of X_c and a decrease of l_a, modifying thus eventually microdeformation mechanisms.

For the study of fracture properties in ductile samples, tensile testing call for certain criticism [5].

It seemed to us interesting to use Essential Work of Fracture (EWF), which is well known as a pertinent tool to investigate on fracture of ductile materials, especially in film geometry [6].

The method will be applied to the study of PP films photooxidation [3].

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